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APPLICATION OF AMORE METHODOLOGY TO MANPOWER, PERSONNEL AND TRAINING FRONT-END ANALYSIS OF NEW MATERIEL SYSTEMS

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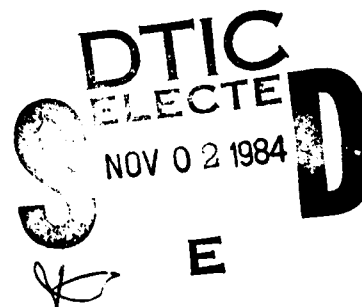SYSTEMS RESEARCH LABORATORY

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report presents a methodology for adapting and applying the Analysis of Military Organizational Effectiveness (AMORE) methodology to manpower, personnel, and training front-end analysis of new materiel systems. The approach is to relate system design alternatives to their impact on the resiliency of the new system and to identify key personnel and training factors which influence that relationship. The effects of potential environmental degradations on system capability are also considered. Specific examples and illustrations are presented to explain the application of the methodology.

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INTRODUCTION

1.1 BACKGROUND

This report presents the results of research conducted under Task 3 of contract number MDA 903-83-C-0118 with the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). The contract encompassed a four task research effort entitled, "Enhancing Force Effectiveness Through Research on Applications of Methodology for Unit and Crew Structuring." The purpose of the contract was to integrate the AMORE methodology with ongoing ARI research efforts to improve the ability of ARI to support TRADOC and DARCOM with their responsibilities in the system acquisition process.

Over the last several years, Science Applications, Inc., has developed a methodology for examining the fundamental relationships between the mission requirements of an organization and its available resources of personnel and materiel. The Analysis of Military Organizational Effectiveness (AMORE) methodology uses the concept of Mission Essential Teams (METs) which define increments of unit capability by establishing the essential personnel and materiel resources required to form each increment. Allowable alternate uses for the available resources are also identified. The AMORE methodology, supported by computer software, is then used to calculate the number of capability levels (METs) which the unit is able to reconstitute over time following degradation of its resources. The output also includes an identification of which resources prevent the organization from achieving a higher level of capability. The various outputs, alone, do not constitute a solution, but do provide the data needed for problem analysis. Additional details of the AMORE methodology are contained in Section 2.2.

AMORE has been used successfully to pinpoint the skills or equipment (or both) which limit the ability of a unit to reconstitute capability from its own resources following degradation of those resources. Based upon that, it has been used to identify and quantify the organizational and training im-

provements which will have the most positive impact on the organizational structure of the unit. More recently, it has been adapted to develop organizational designs which are structured optimally to minimize resources while meeting established criteria of resiliency.

AMORE is a methodology; an approach to quantitative analysis of selected organizational effectiveness issues. If properly adapted for use within credible limits, it is a very effective tool for quantifying the impact of change on a unit's capability. There are three phases to an AMORE analysis: development of input data, exercise of computer software, and analysis of output data. Computer modeling is only a small part of the AMORE methodology. It should be noted that the basic research and approach of the methodology represent a logic worthy of consideration by any organizational analyst or designer.

There are limitations which should be recognized with regard to the application of AMORE. The actions of unit personnel and equipment can not be modeled discretely. The methodology depends on the definition of levels of degradation, levels of morale, unit cohesiveness, training status, leadership environment, and other similar factors from outside sources. It is labor intensive, requiring extensive research and preparation of input data which is heavily dependent upon expert judgement. However, if users are able to accurately quantify the valid representative factors which impact on a unit's effectiveness, the methodology will produce accurate measurement of the effect of those factors on the ability of the unit to reconstitute capability following degradation or on the design of the unit.

There are two validity issues for consideration prior to the use of AMORE as a metric. First, how well AMORE measures what it claims to measure; the ability of an organization to reconstitute capability from its own resources following degradation of those resources (content validity). AMORE is typically used to determine an average response given an average level of degradation. Thus, the AMORE software includes the modeling of stochastic processes and the software output has an associated probability distribution. The standard distribution of, and confidence intervals about, that output are also calculated by the software for use by the analyst. AMORE has been applied

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successfully to many organizational analyses and the operational and analytical leadership of the Army has indicated confidence in these measurements. That confidence is reflected in the policy of the US Army Training and Doctrine Command (TRADOC) that the AMORE methodology be used in the development of all new organizational designs.

The second consideration is how well AMORE can predict actual results in combat (predictive validity). This is obviously more difficult to verify, but at least one previous study effort is applicable. During the Analysis of Military Organizational Effectiveness/Air Base Combat Mission Readiness study, US Air Force sortie generation rates were predicted for an F-15 squadron using the AMORE methodology and then compared with actual results from a specific squadron. The result was a 94% correspondence between the actual number of sorties generated and the number predicted from the AMORE analysis. The generation of F-15 sorties was the measure of combat output for the unit analyzed (Aircraft Generation Squadron). While this single example is far from conclusive evidence on this point, it at least indicates potential utility of the methodology for this type of measurement. The methodology uses the assumption that unit leadership can determine the utilization of available personnel and equipment which will result in the maximum unit capability. Although reconstitution in an actual unit is likely to be sub-optimal, most assignment choices would be obvious to an experienced chain of command. Techniques have also been developed (see Commanders' Kit Training for Reconstitution, 1982) to assist the process at the small unit level.

1.2 APPROACH

Task 3 was envisioned as the theoretical research portion of this contract effort. The research was intended to develop an understanding of ways in which the AMORE methodology could help to accommodate human factors issues at an early point in the development of new Army materiel systems. Effective use of the AMORE methodology requires an understanding of the constructs of unit personnel and equipment requirements. In the early stages of system design, those constructs may not be explicitly known. Since approximately 70% of a typical new system is defined by the end of the Concept Exploration phase (Milestone I), this methodology was expected to be used very early in the

development cycle where it can still have significant impact. The research was to examine ways to deal with these uncertainties and to establish linkages between hardware system alternatives and MPT requirements.

At the beginning of the contract, it was recognized by the sponsor that Task 3 research might not be able to produce the ultimate objective of an AMORE-based methodology which could aid in the development of new materiel system designs. The emphasis was on advancing the utility of the AMORE methodology by the additional research. Because ARI was sponsoring a related project entitled the Early Training Estimation System (ETES) at the same time, it was directed that Task 3 also examined the degree to which ETES could provide input to the AMORE application. That research path led to an examination of the HARDMAN methodology and consideration of the advisability of integrating AMORE with HARDMAN in order to achieve the objectives of the task. A tentative conclusion was reached that HARDMAN and AMORE did not generally overlap, and that each provided valuable input to a complete evaluation of the MPT requirements of new materiel systems. HARDMAN provides necessary information to establish basic MPT requirements. AMORE adds the dimension of sufficiency by adjusting those and additional MPT requirements to provide the best effect on the resulting unit design.

Because the ETES project was terminated a few months after research on Task 3 had begun, and because there was not sufficient timely data available to pursue the HARDMAN-AMORE integration further during the contract, that original research direction was terminated and efforts refocused on basic research into the AMORE methodology. AMORE research concentrated on the effect which changes in major areas of AMORE input data have on unit design and an organization's reconstitution capability using organic assets following degradation of those assets. In particular, the effect of changes of unit authorized strength, MET requirements, and substitutability were examined. Although the remaining time and resources available to complete that research as part of this contract were not sufficient for a complete investigation, it did provide useful information and insights. The details of the research are reported in Appendix B.

The objective of this report is to present a methodology for adapting and applying AMORE to manpower, personnel, and training front-end analysis of new materiel systems. The approach of the methodology is to relate system design alternatives to their impact on the resiliency of the basic organization incorporating the system, and identify key personnel and training factors which influence that relationship. This methodology is applicable for use very early in the development cycle, but also at any later period. It has particular potential for assisting the evaluation of system alternatives as part of the Source Selection process. That methodology is described in Section II while Section III illustrates the process by means of example applications.

SECTION 2

APPLICATION OF AMORE METHODOLOGY TO
MANPOWER, PERSONNEL, AND TRAINING FRONT-END
ANALYSIS OF NEW MATERIEL SYSTEMS

2.1 INTRODUCTION

This section describes a methodology in which AMORE may be used to analyze manpower, personnel, and training (MPT) requirements of new materiel systems. This process is outlined below, described in the remainder of this section, and illustrated by examples in Section 3. The six steps of this methodology are:

STEP 1 - Develop Unit Baseline

> The purpose is to document a baseline capability response for selected current and conceptual units. The approach is to apply the basic AMORE methodology to each unit to determine its ability to reconstitute capability over time from available assets *following degradation and to identify any critical or limiting* skills.

STEP 2 - Analyze Unit Design

> The purpose is to identify the relative leverage of the various personnel skill groups for improving unit resiliency. The approach is to redesign the conceptual unit to satisfy unit resiliency design criteria with minimum personnel resources.

STEP 3 - Select Specific Design Alternatives

> The purpose is to identify specific alternatives to the materiel system design which should be analyzed for their MPT impact. The approach is to examine groupings of task requirements which lend themselves to change with particular emphasis on those which reduce critical skills or emphasize leverage skills previously identified.

STEP 4 - Analyze Personnel Impact

> The purpose is to examine the impact of specific alternatives to the materiel system design on MPT requirements. The approach is to reflect the impact of system alternatives in changes to the unit METs or transfer matrix, and use AMORE to determine the impact on MPT requirements.

STEP 5 - <u>Analyze Degraded Environment</u>

The purpose is to examine the impact of system design alternatives on personnel in a degraded environment. The approach is to develop degraded environment situations which will produce critical skills. Relate the critical skills to system alternatives and quantify the effect on unit resiliency.

2.2 STEP 1 - DEVELOP UNIT BASELINE

The purpose of this initial step is to document a baseline capability response for selected current and conceptual units. The approach is to apply the basic AMORE methodology to each unit to determine its ability to reconstitute capability over time from available assets following degradation, and to identify any critical or limiting skills.

Units are selected for the AMORE analysis based upon their relationship to the new materiel system under consideration. The conceptual unit selected is the one which best represents the primary organization which will utilize the new system. If more than one type unit will be a primary user, it is appropriate to conduct a separate *parallel* analysis for each unit. In that case, it would be most efficient to complete the analysis for one unit and then repeat with the next unit concentrating on differences with the original analysis.

The current unit selected is the one which best represents the primary organization utilizing the system which is a predecessor of the new system. If more than one conceptual unit is selected, a current unit is selected for each conceptual unit. If more than one current system is the predecessor of the new system, sufficient current units will be analyzed to adequately define the current baseline. The analysis of the current unit is used to compare with the analysis of the conceptual unit in this step only and is not required in later steps so, if no current unit can be selected because the new system has no predecessor, analysis of the current unit may be omitted.

Experience with the AMORE methodology indicates that a company-sized unit is normally most appropriate for the purposes of this analysis. Skills and

substitutability are normally represented satisfactorily at this level. A
lower level is not adequate to represent the probable interactions unless
physical separation on the battlefield is expected to prevent those interac-
tions. If that case occurs, a platoon-level organization is adequate for the
analysis. Battalion level analysis may be necessary for systems which link or
cross several echelons. It is never wrong to analyze battalion-sized units
for this purpose if proper care is exercised in developing input data, but the
additional work involved with the larger unit is not worth while in most
cases. Substitution of personnel between battalions will rarely occur in com-
bat, and so use of the basic AMORE methodology at a level above battalion is
not normally reasonable.

In the development of input data for this step, both personnel and equip-
ment will be analyzed, and requirements for each will be identified. The ma-
teriel requirements will often be necessary in order to identify the numbers
and location of personnel requirements, and vice versa. However, it will not
normally be necessary to complete the AMORE analysis of materiel beyond estab-
lishing the unit requirements. Because this application is focused on man-
power, personnel, and training requirements, the assumption is used that any
limiting materiel situations which exist in the units will be corrected with
no impact on MPT requirements. The basic AMORE methodology is very useful in
examining the complex interactions between personnel and equipment to produce
unit capability, but in this situation further analysis of materiel serves
only to increase the workload of the user. If a costing methodology is subse-
quently added to this approach, complete analysis of the materiel requirements
will be necessary in order to provide the total costing requirements.

Before proceeding further, it will be helpful to define a few terms. As
background, suppose a unit is authorized 100 personnel, all with the same
skill and completely interchangeable. Assume further that the capability of
the unit can be divided into 100 increments, each requiring one of the auth-
orized personnel. If that unit loses 10 personnel, its capability is 90%
(i.e., it is able to provide 90 of its 100 increments of capability). If the
10 losses are restored and a different set of 10 are lost, the capability is
still 90%. No matter which 10 personnel are lost, the capability will always

be at least 90% because the unit is not limited by any single skill. However, the capability can never be greater than 90% when 10 personnel are lost because the unit is limited by the surviving population.

- Residual Capability - maximum capability of a unit following degradation and reconstitution.

- Resilient Unit - a unit whose average residual capability equals or exceeds the percentage of survivors (e.g., a unit which has 80% of its personnel survive degradation and can reconstitute to 80% or more of its capability).

- Population Limited - a unit classification meaning that the residual capability of the unit is limited only by the number of survivors (the population). The unit's residual capability cannot be enhanced by improving substitutability.

- Skill Limited - a unit classification meaning that, even with surplus personnel, the residual capability of the unit cannot be increased because of the shortage of one or more specific skills. Residual capability can be enhanced by addition of personnel in a specific skill, or by increasing substitutability for that skill.

- Critical Skill - a unit skill requirement which causes the unit to be skill limited, and which prevents the unit from being resilient.

- Limiting Skill - a unit skill requirement which causes the unit to be skill limited on one or more trials, but does not prevent the unit from being resilient.

The unit baseline analysis is divided into three phases: development of input data, exercise of computer software, and analysis of output data. The following paragraphs describe the details of these phases.

2.2.1 Develop Input Data

The development of input data requires detailed research and analysis. The results obtained from this application will only be as good as the input data. Rough approximations of the output data can provide useful insight, but final measurements of any value require valid input data. Much of the input data is subjective, but thorough functional analysis of the unit and the new (or predecessor) materiel systems, together with the well considered judgement of operational experts, can result in high confidence in the input.

The functions of the unit and how the functions interrelate must be determined. These functions are actions which must be performed to accomplish the mission. A unit mission is selected which will require most of the skill groups so that it will force the unit to draw upon its resources. The mission should make simultaneous demands on multiple functions within the unit. A functional analysis of the mission addresses questions such as:

- Who performs which function?
- In what order are functions performed?
- How long does each take?
- How many people are needed?

The authorized strength of each personnel skill group and the authorized quantity of each equipment type are inputs. These initial strengths specify the total supply available in each category before any degradation.

The user specifies the skill groups and equipment types to be used in the analysis. All personnel authorizations will be included, but only major items of equipment are necessary. Develop a list of personnel skill groups by listing the job title and military occupation specialty (MOS) of each line in the unit TO&E. After the transfer matrix is developed for this listing, the items can be examined for possible aggregation. Aggregation is not necessary, but it can make the data more manageable for the user and more efficient for later use with the computer software. Equipment listings are developed in the same way, but many items are components of, or support equipment for, larger systems and so listing of only the major systems is generally sufficient. It is best to begin by listing too much and then pare the list down to a manageable amount for the user based upon analysis of the unit's functional requirements. For this analysis, equipment requirements are only developed to assist in establishing the personnel skill requirements as explained earlier. If the conceptual unit does not yet have a TO&E or similar listing developed, establish the input data for the current unit first and then develop the personnel and materiel requirements based upon a functional analysis of the conceptual unit and a comparison with the current unit.

A transfer matrix is developed for personnel. It defines authorized substitutions and the penalty which the unit incurs when those substitutions are made. The matrix is of size NxN (N rows and N columns) with identical row and column headings corresponding to the N personnel skill listings. If the A_{ij} cell of the matrix contains a number, it means that the personnel listed in row i are allowed to substitute for the personnel listed in column j. The numbers are unidirectional, i.e., the column skill may not be able to substitute for the row skill. The number in the cell represents the average time in minutes for the substitution to be operational with an acceptable degree of capability. Zeros indicate the substitution is operational immediately. The penalty times include travel, orientation, and review of essential tasks. The diagonal cells (same row and column - A_{ii}) are all zero since they represent the time it takes for a personnel skill to substitute for itself. A cell which does not contain a number indicates that substitution is not allowed, either because it is not feasible (e.g., training shortfall) or it is not reasonable (e.g., the First Sergeant can substitute for a Private, but it is not normally reasonable).

Mission essential teams (METs) define increments of unit capability. METs are developed by establishing the minimum essential personnel and materiel resources required to form each increment. METs for line units are normally built around increments of combat capability such as an infantry squad or a howitzer section. For headquarters units, METs are usually built around levels of command and control while combat service support unit METs are increments of combat support. There is never a unique number of increments for a unit, but a thorough analysis of the unit functions will narrow the reasonable options and identify diverse functions which will be integrated (e.g., maintenance and support, command and control, and fire support). Experience with AMORE has shown that at least five increments are desirable in order to provide reasonable output, because otherwise the percentage of unit capability represented by each increment is very large which can skew the results (e.g., with three increments, each one represents 33% of the total unit capability). More than 20 increments become slow and difficult for the user to work with for little if any improvement in results. The personnel skills and equipment assigned to a MET must be essential to the team. By definition, the team cannot perform its function without all of its required personnel skills and

materiel items. Skills and equipment which do not meet this criteria should not be included. Teams do not have to be either linear or homogenous. Where possible, however, it is best to develop equal increments of capability and have each team represent that equal increment.

Personnel degradation is assessed stochastically by the computer software, but the level of degradation is developed by the user as an input. To develop the output needed for this application, parametric sets of degradation are used. This allows an investigation of the unit's response to a spectrum of degrading situations. The actual values of degradation used are arbitrary, but the following three characteristics are desirable: equally spaced over the interval of interest (typically from 0% to 50%), close enough to indicate where changes in capability occur (at least three intervals), and not too many intervals (excessive work for little benefit - 10 is maximum). A recommended procedure is to choose degradation levels which correspond to the incremental loss of METs. In a unit with 10 METs, for example, the loss of one MET corresponds to 10% degradation, two METs to 20%, etc. In this case, degradation levels of 10%, 20%, 30%, 40%, and 50% would be selected for analysis. This procedure allows for a more direct identification of critical skills in the following analysis by directly relating the number of METs which the unit should be able to reconstitute to the level of degradation.

There are other inputs of less interest which are oriented on the particular version of computer software employed to present output in the desired format. The software user's manuals should be consulted for additional details [Apple II Computer Version, 1983, and User's Handbook, 1982].

2.2.2 AMORE Software

The AMORE software applies degradation stochastically to the authorized resources of the unit, so multiple iterations are necessary to produce statistically acceptable results. Experience has shown that at least 30 but not more than 50 iterations are necessary for this purpose. Each iteration consists of applying damage to the unit and assessing the number of survivors, optimally reallocating the surviving resources to build the maximum number of

teams, and calculating unit capability at selected times after the degradation.

A uniformly distributed random number is generated by the software for each skill group listing and compared to the probability of degradation. A set of survivors by skill group listing is then determined for each iteration.

After degradation, the software calculates the maximum number of teams that can be reconstituted from the survivors. It accomplishes this by using a binary search technique combined with a transportation algorithm. The binary search technique searches for the level of capability that can be built with a given set of survivors. For example, in a unit with 15 METs, the algorithm will first attempt to build eight METs. If they can be built, the next trial will be for 12 METs; if not, then four METs. Successive trials split a smaller and smaller bracket until a level is reached which can be built while the next higher level can not. This is continued for each iteration in order to develop a distribution of capability response.

A transportation algorithm is used to calculate optimal allocation of personnel assets to requirements. The algorithm selects from survivors to match MET requirements in such a way that the average time penalty per assignment is minimized. Thus, the entries in the transfer matrix serve as a prioritization guide as each trial begins anew to select the set of skill allocations which will minimize the total penalty time.

2.2.3 Analyze Output Data

There are three elements of output data which are of primary interest for this analysis: capability at selected times, needs and surpluses, and assignment matrices. There are some other elements of output data available and some options on how that data is prepared, but these elements are generally sufficient for the application in this report. The user is referred to the software user's manual for detail on other options available with specific software.

The capability output data contains the average fraction of unit capability evaluated at each of the selected time intervals. This is the primary output for the software. It includes the capability immediately after degradation (zero time), the minimum capability, and the maximum capability (infinite time). A 90% confidence interval about the average capabilities is included in the output for each time interval.

The needs and surplus data is an optional output which is essential for the identification of critical and limiting skills. The software performs a choke analysis for each iteration in which the maximum number of METs which can be formed is less than the total number of teams. The choke analysis identifies the personnel skill groups which are needed in order to build one more team. This output data includes the average needs for each personnel skill group, the average surpluses, and the standard deviation of these averages.

The assignment matrices consist of the average assignment frequency of survivors for those iterations used to build a particular maximum number of teams. Used together with the needs and surpluses data, it is helpful in understanding the substitution interactions which need to be improved or which have high payoff.

The capability output data provides the measure of the unit's ability to reconstitute capability over time from available assets following degradation. It will be of some interest in later steps of this application to use the time parameter to examine certain personnel or training policy consequences, but the residual capability is most important in this step. Residual capability is the maximum capability which the unit achieves for each level of degradation.

A graphical portrayal of this data which is useful in the analysis phase is called the unit capability chart. An example of this type display is shown in Figure 2-1. The "efficient balance" line shown on the figure is a reference line showing balance between resources and capability. Data points on or above that line generally indicate a population limited unit. Data points
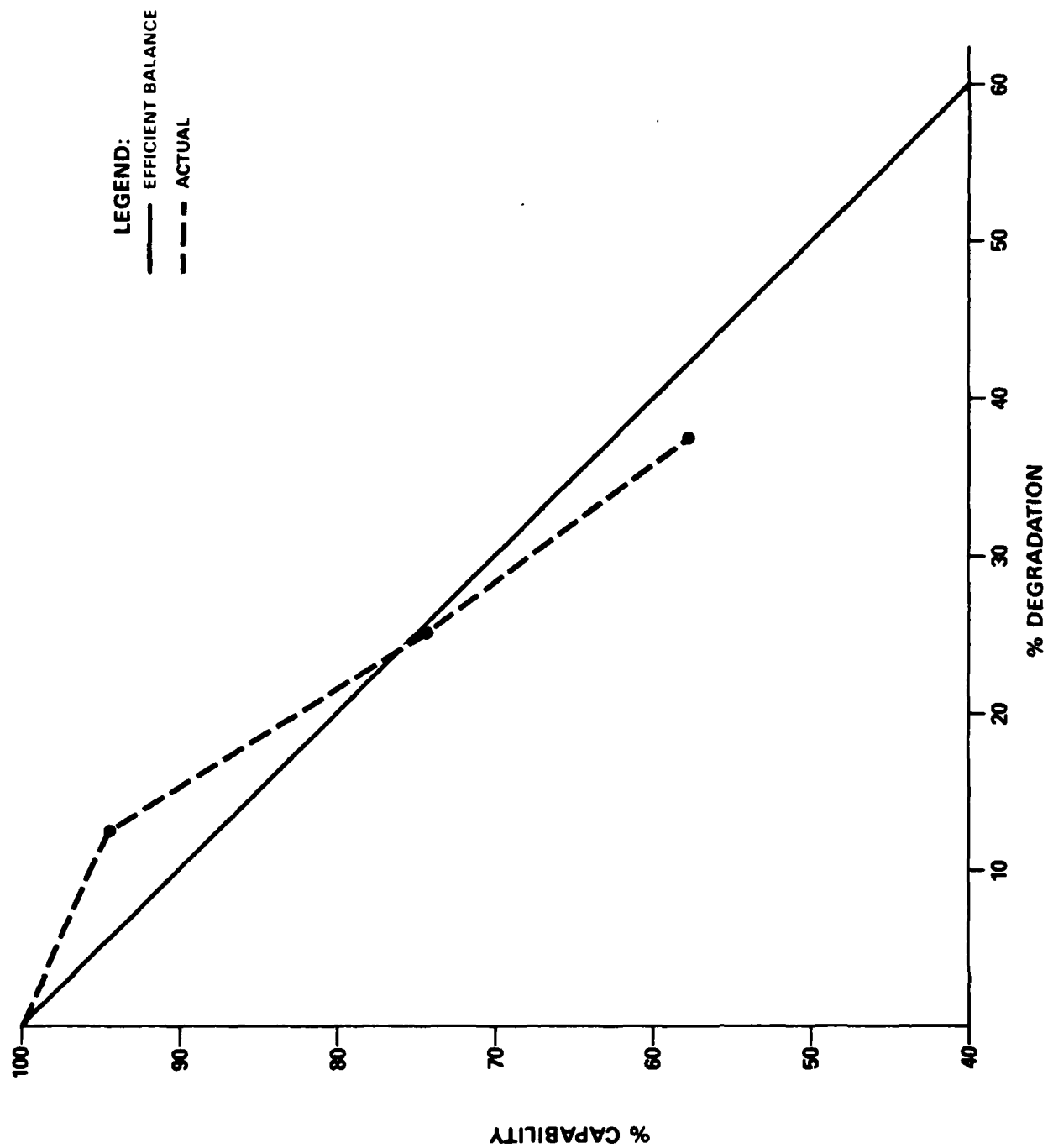
FIGURE 2-1. UNIT CAPABILITY CHART

LEGEND:
——— EFFICIENT BALANCE
– – – ACTUAL

% DEGRADATION

% CAPABILITY

below the line generally indicate a skill limited unit. By definition, skill groups which cause the unit capability to be below the efficient balance line are critical skills. If capability plots above the line, the unit does not have critical skills (at that level of degradation), but it may well have limiting skills. When a unit is skill limited, it is normally losing capability at a faster rate than it is losing resources. Unit response rarely plots completely above the reference line, but normally crosses over and falls below it at some level of degradation. A unit is considered resilient up to the level of degradation where its capability falls below the efficient balance line.

All critical and limiting skills will be identified at this point in the analysis. The current and conceptual units are compared in order to identify key differences in unit capability response and the skill groups which have the greatest effect on that change in response. The current unit analysis is used to better understand the changes brought about by the conceptual unit and the new materiel system. At very early stages in the developmental cycle of this new system, the current unit analysis will be particularly important as the basis of measurement for change. The conceptual unit analysis also becomes the baseline against which the analysis in subsequent steps is compared.

2.3 STEP 2 - ANALYZE UNIT DESIGN

The purpose of the next step is to identify the relative leverage of the various personnel skill groups for improving unit resiliency. The approach is to adjust the personnel skill allocations of the conceptual unit so as to satisfy unit resiliency design criteria with minimum personnel resources.

The design criteria include a specification of the total number of mission essential teams (increments of capability) required after combat degradation and reconstitution (design goal), and the required assurance for meeting the required capability. The same METs and Transfer Matrix developed in Step 1 are used in this process. The number of personnel required to form the design goal (required) number of teams is determined. Calculations are then made, considering degradation and statistical variance, to determine lower and upper bounds on the additional number of personnel needed to meet the design

criteria. Personnel are added in priority in accordance with an algorithm to form lower and upper bounds on the optimal design. The AMORE software is applied at the lower and upper bounds to establish a bracket. The bracket is then split successively by adding or subtracting personnel in priority. New bounds are established and the process repeated until the design criteria are met with minimum resources. The tentative design is verified to insure it will meet all criteria.

At the conclusion of this step, the conceptual unit will have been redesigned to identify the personnel necessary to meet the mission essential requirements at a minimal resourcing level. That process will be useful in identifying the relative leverage of the different skills authorized in the unit in improving unit resiliency.

This unit design process was developed and reported by SAI in a study effort for the U.S. Army Armor School [Hannon, Robinson, and Stenstrom, 1983]. It has been adapted for this application and is reported here in sufficient detail to allow the reader to use it for this purpose without reference to other sources. However, the above listed reference contains much additional detail and explanation which the user is encouraged to examine. The following description assumes that the METs and Transfer Matrices have already been developed as part of Step 1. The actions necessary to reach the final unit design follow.

2.3.1 Establish Unit Design Criteria

At a minimum, the user must specify a mission or set of missions, a design goal of capability, a level of degradation against which the unit is to be made resilient, and a level of assurance for meeting the design goal capability. Usually the unit is designed against the most critical mission/required capability/degradation combination and then tested against other combinations. At times, a most likely combination of those factors, or even a range of their combinations, may be preferrable. A capability goal should also be specified and tested for the unit with no degradation. This will be used after the unit is redesigned to insure no requirements have been omitted.

An example of unit design criteria for a unit with 10 METs might be:

- mission - 72 hour delay
- design goal - 8 METs
- level of degradation - 20%
- level of assurance - 90%
- undegraded goal - 10 METs

2.3.2 Establish Substitutability Factors

The strategy for selecting add-ons is to choose skills which can substitute for those skills which have the least available substitutes. This tactic will increase the available substitutes for the skills which were most limited previously, and thus tend to eliminate critical or limiting skills. When more than one skill meets that criteria for the next add-on, the one which can substitute for the most other skills is selected first. This improves the overall substitutability of the unit the most. These two substitutability factors - (1) number of substitutes possible into a skill, and (2) the number of substitutions possible from a skill into others - are integral to the development of a prioritized add-on list, and so are developed at this point for subsequent use.

Both factors may be readily obtained from the personnel transfer matrix. Factor (1) is the number of entries in a column (not counting the "0" on the principal diagonal), and factor (2) is the number of entries in a row (not counting the "0" on the principal diagonal).

2.3.3 Establish Add-ons

A calculation of the minimum increment of personnel by skill group necessary to be added to the design goal MET in order to achieve design criteria is made at this point. The lower bound compensates for the average loss of authorized personnel. Adding the lower bound to the MET requirement will probably not satisfy the design criteria because it does not account for variability in averaging the loss.

An add-on to the lower bound is calculated to compensate for variability extremes in losses. The total personnel add-on is called the upper bound. While the lower bound will fall short of meeting the design criteria, the upper bound will overshoot the mark. These bounds will be split sequentially until a best solution is identified.

2.3.4 Establish and Apply Priorities for Add-ons

There are many possible techniques for prioritizing add-ons to the required METs to reach lower bound, upper bound, and any intervening strength levels as a basis for the sequential bracketing process. However, an underlying principle, which accomodates the multiple possibilities of substitutability which can occur, is to select as first priority add-on the MET skill group which has the fewest skills which can substitute for it (lowest factor "1"). Assign to that skill group the skill group which can substitute into the most other skills (highest factor "2"). This will ensure that the unit substitutability is improved the most.

List for each skill group the skills or substitutes to be added until a user add-on priority rule is satisfied. Also, a priority number is determined which establishes the order in which skill groups are considered for add-on. Translate the prioritization sequence into a list of skills to be added in order of priority.

2.3.5 Determine Optimum Design

A minimum of three cases are initially developed and tested: a lower bound, middle bound, and upper bound. These are developed by adding enough of the items from the prioritized list to the design goal MET to reach the lower, middle, and upper bound strength levels. Each case is then input to the AMORE software as the initial strength. These AMORE runs establish bounds on the optimal solution.

The initial strength bounds are successively split, based upon the results of sequential AMORE calculations of capability, until the minimal resources necessary to achieve the design criteria are identified. Although all splitting techniques should result in convergence at the same level of add-on,

the speed of convergence is of concern. Binary search techniques are normally most efficient. If the middle bound is run first, the second trial should be the bound in the opposite sense, i.e., if the middle bound is "too low", then the upper bound should be tried next realizing that this will create the appropriate bracket. In this case, the lower bound will never be needed because the middle bound has become a "better" lower bound.

The minimal sufficient set of resources to meet the primary design criteria are tested against other design criteria and adjusted if necessary. The final test is to see if the accepted resource level can satisfy the requirements of the full MET goal with no degradation. This assures that the optimizing changes and adjustments have not overlooked any aspect of the full MET requirements.

2.4 STEP 3 - SELECT SPECIFIC DESIGN ALTERNATIVES

The purpose of this step is to identify specific alternatives to the materiel system design which should be analyzed for their manpower, personnel, and training impact. The approach is to examine groupings of task requirements which lend themselves to change with particular emphasis on those which reduce critical skills or emphasize leverage skills previously identified.

This process properly begins with an examination of the functional requirements of the predecessor system and the new materiel system, and an identification of the corresponding required tasks for system operators and maintainers. A bottom-up approach of identifying tasks associated with specific hardware sub-systems based upon an analysis of comparable equipment which performs similar functions in similar environments is appropriate. Based upon this approach, the task differences between the predecessor and the new materiel systems are related to the design differences between the two systems.

Operational and maintenance tasks for the new system are then compared to the characteristics of existing MOSs as described in AR 611-201 and other sources to identify the closest match. Differences are noted. How well the closest identified MOS is able to perform the comparable tasks on the current

system and the similarities of the operational context in which those tasks are to be performed determine the magnitude of new training and MOS requirements. Similarly, a determination is made of grade requirements within the MOS based upon skill (proficiency) levels and supervisory positions required. The purpose at this point is not to compute requirements, but rather to identify and isolate the important relationships between hardware sub-systems, and manpower and training requirements.

This function/task analysis is now integrated with the AMORE process. The function/task analysis does not have to be accomplished, however, in order to complete Step 3. Step 3 could begin at this point if the objective is just to obtain relative comparisons and insight about system design alternatives.

Step 1 (paragraph 2.2) resulted in the identification of any critical or limiting skills. If ways can be developed to remove the choke caused by those skills, then unit resiliency can be improved most effectively at that level of degradation. One approach is to add more of the critical skill personnel to the unit authorization, but that solution is not typically acceptable at this point. Solutions which require the same or fewer resouces are the goal.

The preferred approach is to identify hardware sub-systems, or even specific functions of a sub-system, which have a significant impact on the requirement for critical skills. The objective is to select specific changes to the materiel system design which will eliminate the task requirements of an identified critical skill or at least reduce those task requirements to a point where they could be combined with another skill. This design analysis may be done on a relatively gross scale (i.e., the design change may be stated in only very general terms such as changed functional requirements) in order to examine the impact of that resulting personnel change on the unit response. If the unit response is deemed significant enough to warrant more detailed analysis, then a very careful function/task analysis should be undertaken.

If sufficient task analysis data is available, it should also be examined for possible clusters of same or closely related tasks. Also information on

the frequency, complexity, and typical duration of tasks is desired. The objective of this examination is to identify tasks, and their corresponding hardware origin, which have high leverage impact on the MPT requirements. Again, changes to the materiel system design should be selected which would change those identified task requirements.

At the conclusion of this step, new materiel system design alternatives have been identified and selected for further examination with regard to their MPT impact.

2.5 STEP 4 - ANALYZE PERSONNEL IMPACT

The purpose of this step is to examine the impact of specific alternatives to the materiel system design (from Step 3) on manpower, personnel, and training requirements. The approach is to reflect the impact of system alternatives in changes to the unit METs or transfer matrix, and use AMORE to determine the impact on MPT requirements.

The effect of those design alternatives on mission essential requirements are reflected in changes to the METs. If alternatives include the elimination of sufficient total task requirements so that less manpower is required, then changes to the authorized unit strength are also appropriate. If these changes affect the complexity or uniqueness of tasks, then the allowable substitutions should be reviewed and changed as appropriate. Care must be taken to identify all aspects of the effect of the changes. For example, a new device which eliminates operator requirements will very likely add maintenance requirements at several echelons above the operator.

Before conclusions are reached about the advisability of reducing MET requirements or the unit strength authorization, the additional support task requirements should be considered. These are not typically part of a materiel system function/task analysis since they are part of the unit's operational mission requirement. These tasks may not be well documented and easily quantified, and so additional research and analysis may be necessary.

Several different training situations could be examined in this analysis ranging from a unit where personnel are very narrowly trained in their own MOS (e.g., only capable of accomplishing their own MOS tasks at grade level and below) to a unit which is broadly cross trained beyond normal career management field boundaries (e.g., maintenance and administrative personnel able to accomplish weapon system crew tasks, and sufficient crew members able to accomplish essential maintenance and clerical tasks). These differences would be reflected in the transfer matrix by changing the allowable substitutions. The reasonableness of a substitution should continue to constrain increased feasibility.

In general, a variety of personnel impacts on the unit are examined at this step. Emphasis is on the impact from actual or postulated materiel system design alternatives, but other factors such as training should be examined for their impact. The resiliency of the conceptual unit following various levels of degradation is a major indicator of the impact of these changes. An examination of the personnel needs and surpluses output will help in identifying critical and limiting skills and in examining the impact of various changes on those skills. Unit capability as a function of time output will provide an additional measure of effectiveness by using it to calculate effective unit hours of performance.

2.6 STEP 5 - ANALYZE DEGRADED ENVIRONMENT

The purpose of this step is to extend the analysis of the previous step to examine the impact of system design alternatives on personnel in a degraded environment such as that produced by fatigue, reduced teamwork, or a chemical warfare environment. The approach is to develop degraded environment situations which will produce critical skills. Relate the critical skills to system alternatives and quantify the effect on unit resiliency.

Units can be categorized as either skill or population limited. Skill limited units have capability response constrained by the shortage of specific skills; personnel in other skills are available but unable to substitute. Population limited units do not have their capability response constrained by

one or more specific skills but only by the number of personnel ("survivors") available. Based upon extensive experience with the AMORE methodology, units which contain major weapon systems generally are population limited. The category which the conceptual unit falls into can usually be determined in Step 1 (unit baseline) of this process. If the unit is personnel limited, its response in a degraded environment should be investigated to discover if there are critical skills under some special circumstances. In most cases, critical skills can be identified.

Fatigue is typical of the type of degradation to individuals which does not eliminate them from the unit but which reduces their effectiveness. It affects the cognitive skills of personnel, and thus will reduce their ability to perform tasks requiring a higher cognitive level than their own skill. A general approach to applying the effects of fatigue to an organization is to rate and then rank order each position by its cognitive difficulty, and then translate that ranking to an effect on substitutability. One reasonable approach is to eliminate any substitutions from one job to another job which is higher on the rank ordered list. This will reduce the substitutability of the unit and, therefore, make the presence of critical personnel more likely in the unit.

Another category of personnel degradation is the effect which substitutions will have on teamwork. As substitutions are made (e.g., during reconstitution), the teamwork of a unit is reduced which results in lower unit effectiveness. Through this process, some of the adverse consequences of substitution as an alternative to system hardware solutions, or as a part of the tradeoff of those solutions, can be examined.

One way to measure productivity is the ratio of an individual's degraded duty cycle to his fully productive duty cycle. Let P_1, P_2, and P_3 be the rates at which three different members of a team can perform their job relative to a fully productive standard. Let H_1, H_2, and H_3 be the available productive hours per day of the same team members. Then the products ($P_1 \times H_1$, $P_2 \times H_2$, and $P_3 \times H_3$) are a measure of the degraded productivity of the team members.

At the lowest end of the teamwork scale, team performance is limited by the least productive member. Other members are awaiting completion of sub-tasks so that they can continue, or have finished and are waiting to begin the next team task. As team training increases, the time spent by others waiting can be reallocated to help the less productive members. Let H_{12} represent the time reallocated from member 1 to member 2, etc. If teams are fully trained, this reallocation can be done efficiently so that the team productivity is optimized. Let P be that optimized rate of productivity. Then by definition under the ideal reallocation, where P_1 is the highest rate and P_3 the lowest,

$$P_1 (H_1 - H_{12} - H_{13}) = PH_1 \tag{1}$$
$$P_2 (H_2 - H_{23}) + P_1 H_{12} = PH_2 \tag{2}$$
$$P_3(H_3) + P_1 H_{13} + P_2 H_{23} = PH_3 \tag{3}$$

If we solve equations (1), (2), and (3) for the value P, we determine that,

$$P = \frac{P_1 H_1 + P_2 H_2 + P_3 H_3}{H_1 + H_2 + H_3} \tag{4}$$

Thus, the optimal rate of productivity, P, is the sum of the three individual productivities divided by the total manhours per day available for the three team members. This same development can be extended to as many team members as desired.

While equation (4) may be calculated off-line, the Apple AMORE software includes a utility program called Personnel Degrader (PERDEG) which will convert input on productivity rates for each member of the MET into capability over time for the unit at both ends of the teamwork scale (i.e., no team training up to full team training). This band of capability performance for the unit will be used to quantify various levels of team training.

Although the approach to examining a chemical warfare environment is very similar to that for unit teamwork, the rationale in developing the input is

much different. The major effect to be examined is the productivity loss produced by the chemical protective garments and mask.

The individual productivity loss in this environment is directly related to the energy requirements of tasks to be performed although other factors such as dexterity and equipment compatability are contributors. Higher energy tasks (heavy labor) produce higher levels of heat for the body to eliminate. However, the protective equipment dramatically lowers the allowable rate of heat elimination by the body. The consequence, if incapacitation is to be avoided, is an increased amount of rest in the work-rest cycle. That, of course, results in a lower rate of productivity. Air temperature and humidity are important variables. Their impact may be treated parametrically or a typical weather day may be selected for analysis. There are many models and procedures available to calculate reduced individual productivity rates resulting from chemical protective equipment.

The PERDEG program of the Apple AMORE model can calculate the difference in unit productivity in the various degraded environments given these individual degradation inputs. This analysis will also demonstrate which skills have the greatest impact on unit productivity in this environment. Based upon those calculations, the benefit of devices to reduce selected heavy labor tasks to light labor, or even eliminate the task requirement, can be quantified. This will help to identify high payoff design alternatives or support equipment which will correct identified problem areas. Alternatives such as better "protective environment" (e.g., a shelter or an enclosed vehicle with air filtration system) in which to perform the required tasks may also be quantified.

This step uses the AMORE methodology to translate individual personnel capabilities and responses into their impact on unit capability over time after being degraded. It is not reasonable to look for a single answer or factor as "the answer", but instead the analyst should use AMORE as described to examine the depth of the materiel system design relationship to manpower, personnel, and training.

SECTION 3

EXAMPLE APPLICATION

3.1 INTRODUCTION

The purpose of this section is to provide additional explanation and application to specific examples to illustrate the methodology presented in Section 2. The objective is to provide sufficient detail about the methodology that no other AMORE references (except user handbooks for specific software options) will be required by the reader.

It is beyond the scope of this section to develop sufficiently every aspect of the research which could be employed in the application of this methodology, but this report will at least describe how to develop and interpret required input data, and how the output data can be applied. It will still be necessary for the user to conduct sufficient research into the proposed materiel system of interest as well as comparable current systems in order to understand the impact of system hardware, operational and support concepts, capabilities of individuals with applicable skills, and training requirements and procedures.

For several reasons, the Division Support Weapon System (DSWS) was selected for use in this section as an illustrative example of a materiel system in an early stage of development. It was a clear illustration of a new system whose design features result in reduced crew requirements. It was far enough along in the development process that a reasonable amount of conceptual and design data was available, but not so far along that the system design was finalized. The predecessor system to the DSWS, which is important as an analytical baseline, is the M109 series 155-mm self-propelled howitzer. The major differences between the DSWS and the M109 howitzer are reasonably obvious and their likely impact on manpower and training are relatively apparent. That situation facilitates their usefulness as an illustrative example in this research. Finally, the availability of previous research work by ARI and SAI on the M109 series howitzer crew [Crumley, Schwalm and Coke, 1982, and

Robinson and Hannon, 1982] provided approved AMORE input data for a current
unit as well as useful data on other task requirements of crew members. Be-
cause the referenced research used the Division-86 battery organization, that
unit design is also used here. Although that design is just beginning imple-
mentation, it is approved for full implementation and is expected to be the
organization which would be replaced by the DSWS battery.

The DSWS Self-Propelled Howitzer (SPH) will be an armored, full tracked
howitzer equipped with a 155-mm gun and either a semiautomated or fully auto-
mated loader and ammunition handling system. It will be manned by a crew of
three to four, but capable of operation by a crew of two. The SPH will incor-
porate a fully automated fire control system consisting of an inertial mea-
surement unit which provides accurate position location and azimuth reference,
an Enhanced Position Location Reporting System (PLRS) User Unit to facilitate
"common grid" and automatic reporting, an on-board ballistic computer, and
computer controlled gun drive servos. This combination will permit "shoot and
scoot" tactics and accommodate the dynamics of high firing rates. Emplacement
and displacement times will be less than 60 seconds. Digital data and voice
communications systems will enable the use of autonomous on-board technical
fire control.

The SPH is paired with an Ammunition Resupply Vehicle (ARV) which will
have organic materiel handling equipment and carry 100-150 complete rounds of
howitzer ammunition. It will be fully tracked and armored (same level as SPH)
with a crew of three to four. It will provide ammunition and fuel resupply to
the SPH.

The M109 series howitzer is an armored, full tracked howitzer equipped
with a 155-mm gun and a manual loading and ammunition handling system. It is
manned by a crew of ten. It has none of the other features described above
for the SPH.

Time and resource limitations precluded an examination of a spectrum of
different units in this report. It must be emphasized that other type units
will react differently to the same levels of degradation, particularly units
that are typically skill limited as opposed to those units that are typically

population limited. Thus, the results for the DSWS and M109 units which follow are intended to illustrate the application and techniques, and not to produce universal truths about all organizations.

3.2 UNIT BASELINE

The first step is to develop the AMORE software input data and then use the output data to establish a baseline of the capability with respect to time following the application of degradation for both the current and conceptual units. Since the DSWS SPH is the new materiel system to be examined, a baseline analysis for the Division-86 howitzer battery as well as for the DSWS firing battery is developed in the following sections.

3.2.1 Div-86 Howitzer Battery Input Data

The Table of Organization and Equipment (TOE) used for the Division-86 155mm howitzer battery is TOE 6-367J. The battery has 129 personnel organized as shown in Table 3-1. There are eight howitzer sections in the battery capable of operating in either a consolidated battery configuration or as separate four-gun platoons, each with an associated platoon headquarters, fire direction center, and ammunition section. Communications support in the form of a wire laying team is provided by the Communications Section. The Battery Headquarters Section provides normal command, food service, supply, and NBC support. Significant items of equipment authorized by the TOE are shown in Table 3-2.

The major functions which this unit must accomplish are tactical command and control, communications, technical command and control, operation of the howitzer, resupply of ammunition, and self defense. These must be accomplished on a 24-hour basis for an extended period of time.

It should be noted that the AMORE software developed for the Apple II computer includes a subroutine to transform essential tasks, their frequency, and their time requirements into MET composition. The Mission Essential Team Builder (METBLD) routine is ideally suited for the situation where METs are not already available for the current organization. That capability was not used here because the baseline unit METs were already available and the

Table 3-1. Personnel, Division-86 Howitzer Battery

Section	Skill	Rank/Grade	MOS	No.
BTRY HQS	BTRY CDR	CPT	13E00	1
	FIRST SGT	E-8	13Y5M	1
	FOOD SVC SGT	E-7	94B40	1
	SPLY SGT	E-6	76Y30	1
	NBC NCO	E-5	54E20	1
	FIRST COOK	E-5	94B20	1
	ARMORER	E-5	76Y20	1
	COOK	E-4/3	94B10	3
	VEH DVR	E-3	13B10	1
COMMO SECT	TAC COM CH	E-6	31V30	1
	TAC WIRE OP CH	E-5	36K20	1
	TAC WIRE OP SPEC	E-4/3	36K10	2
2-PLT HQ	PLT LDR	LT	13E00	2
	PLT SGT	E-7	13B40	2
	VEH DVR	E-3	13B10	4
2-FDC	FIRE DIR OFF	LT	13E00	2
	CH FD CMPTR	E-6	13E30	2
	SR FD SPEC	E-5	13E20	2
	FD SPEC	E-4/3	13E10	6
	CP CARR DVR	E-4	13E10	2
8-HOW SECT	CH SECT	E-6	13B30	8
	GUNNER	E-5	13B20	8
	AMMO TM CH	E-5	13B20	8
	CANNONEER/ASBLR	E-4	13B10	8
	HOW DVR	E-4	13B10	8
	AMMO VEH DVR	E-4	13B10	8
	CANNONEER	E-3	13B10	32
2-AMMO SECT	SECT CH	E-6	13B30	2
	AMMO SPEC	E-4/3	13B10	4
	SR AMMO VEH OP	E-5	64C20	2
	AMMO VEH OP	E-4	64C10	4

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Table 3-2. Materiel, Divison-86 Howitzer Battery

Section	Description	No.
BTRY HQS	Radio, AN/VRC-46	2
	TRK, Utility, 1/4 ton	2
	TRK, Cargo, 2 1/2 ton	2
	TRLR, Cargo, 1/4 ton	2
	TRLR, Cargo, 1 1/2 ton	1
	TRLR, Tank, Water, 400 gal.	1
COMMO SECT	TRK, Cargo, 1 1/4 ton	1
	TRLR, Cargo, 3/4 ton	1
2-PLT HQ	Aiming Circle	6
	Radio, AN/VRC-46	2
	TRK, Utility, 1/4 ton	2
	TRK, Cargo, 1 1/4 ton	2
	TRK, Cargo 2 1/2 ton	2
	TRLR, Cargo, 1/4 ton	2
	TRLR, Cargo, 1 1/2 ton	2
2-FDC	Carrier, CP	2
	Computer, Gun Direction	2
	FD Set, Artillery	4
	Generator, Gas	4
	Radio, AN/VRC-46	6
8-HOW SECT	Carrier, Cargo, 6 ton	8
	Howitzer, SP, 155mm	8
2-AMMO SECT	GOER, 8 ton	6
	TRLR, Ammo, 1 1/2 ton	6

subroutine was not available until late in the research period of this report. However, its present availability should be kept in mind.

As is normally the case for line units, METs for the howitzer battery are defined in terms of the unit's basic fighting element; the howitzer section. Two basic considerations govern the definition of these METs: (1) the battery and section must be capable of 24-hour operations, and (2) the battery must be capable of operating either from a consolidated location or from two separate platoon positions.

The personnel Mission Essential Teams (METs) are shown in Table 3-3 and the materiel METs in Table 3-4. The following subparagraphs summarize the rationale for the composition of those METs.

(1) Along with the first howitzer section (MET), there is a need for a minimal communications section, a fire direction center, and one element of an ammunition section. With only a single howitzer section, there is no need for either a Platoon Leader or a Battery Commander. Two drivers are included in the platoon headquarters to drive the battery prescribed nuclear load vehicles.

(2) With the addition of the second howitzer section, it is necessary to add the Platoon Leader, Platoon Sergeant, and driver. A second element of the ammunition section is also added.

(3) The third howitzer section requires only the addition of the remaining element of the first ammunition section.

(4) The fourth howitzer section requires no additions.

(5) The Battery Commander, First Sergeant, and driver are added with the fifth howitzer section since the span of control capability of the first Platoon Leader begins to be exceeded. An element of the second ammunition section is also added.

(6) The second Platoon Leader, Platoon Sergeant, driver, and a wireman are added with the sixth howitzer section when splitting the battery into two 3-gun platoons becomes a possibility. A second element of the ammunition section is added.

(7) The remaining element of the second ammunition section is added with the seventh howitzer section.

(8) The eighth and final howitzer section requires no additions.

Table 3-3. Division-86 Battery Personnel METs

			MET STRUCTURE							
			TM1	TM2	TM3	TM4	TM5	TM6	TM7	TM8
01	BC	13E0	-	-	-	-	1	-	-	-
02	1SGT	13Y5	-	-	-	-	1	-	-	-
03	DVR	13B1	-	-	-	-	1	-	-	-
04	SPLSG	76Y4	-	-	-	-	-	-	-	-
05	ARM	76Y2	-	-	-	-	-	-	-	-
06	NBCSG	54E2	-	-	-	-	-	-	-	-
07	FSSGT	94B4	-	-	-	-	-	-	-	-
08	COOK	94B-	-	-	-	-	-	-	-	-
09	COMCH	31V3	1	-	-	-	-	-	-	-
10	WIRSP	36K-	2	-	-	-	-	1	-	-
11	PLLDR	13E0	-	1	-	-	-	1	-	-
12	PLSGT	13B4	-	1	-	-	-	1	-	-
13	DVR	13B1	2	1	-	-	-	1	-	-
14	FDO	13E0	1	-	-	-	-	-	-	-
15	CHFDC	13E3	1	-	-	-	-	-	-	-
16	SRFDS	13E2	1	-	-	-	-	-	-	-
17	FDSP	13E1	4	-	-	-	-	-	-	-
18	CH/S	13B3	1	1	1	1	1	1	1	1
19	GUNR	13B2	1	1	1	1	1	1	1	1
20	CREW4	13B1	3	3	3	3	3	3	3	3
21	CREW3	13B1	4	4	4	4	4	4	4	4
22	AM CH	13B2	1	1	1	1	1	1	1	1
23	AM CH	13B3	1	-	-	-	1	-	-	-
24	AMMO	13B1	-	1	1	-	-	1	1	-
25	DVR	64C-	1	1	1	-	1	1	1	-
TOTAL			24	15	12	10	15	16	12	10
CUMULATIVE			24	39	51	61	76	92	104	114

Table 3-4. Division-86 Battery Materiel METs

		MET STRUCTURE							
		TM1	TM2	TM3	TM4	TM5	TM6	TM7	TM8
01	RADIO	-	-	-	-	1	-	-	-
02	TRK, 1/4 T	-	-	-	-	1	-	-	-
03	TRK, 2 1/2 T	-	-	-	-	-	-	-	-
04	TRLR, 1/4 T	-	-	-	-	1	-	-	-
05	TRLR, 1 1/2 T	-	-	-	-	-	-	-	-
06	TRLR, WTR	-	-	-	-	-	-	-	-
07	TRK, 1 1/4 T	1	-	-	-	-	-	-	-
08	TRLR, 3/4 T	1	-	-	-	-	-	-	-
09	AIMING CR	1	1	-	-	1	1	-	-
10	RADIO	-	1	-	-	-	1	-	-
11	TRK, 1/4 T	-	1	-	-	-	1	-	-
12	TRK, 1 1/4 T	-	-	-	-	-	-	-	-
13	TRK, 2 1/2 T	2	-	-	-	-	-	-	-
14	TRLR, 1/4 T	-	1	-	-	-	1	-	-
15	TRLR, 1 1/2 T	1	-	-	-	1	-	-	-
16	CARR, CP	1	-	-	-	-	-	-	-
17	CMPTR	1	-	-	-	-	-	-	-
18	FD SET	-	-	-	-	-	-	-	-
19	GEN SET	1	-	-	-	-	-	-	-
20	RADIO	3	-	-	-	-	-	-	-
21	CARR, 6T	1	1	1	1	1	1	1	1
22	SPH	1	1	1	1	1	1	1	1
23	GOER, 8T	1	1	1	-	1	1	1	-
24	TRLR, 1 1/2 T	1	1	1	-	1	1	1	-

The next step is to prepare transfer matrices for the TOE personnel and materiel. These sets of input data are statements of which personnel skills can substitute for other skills, given time for travel, orientation, and minimum essential review of functions, and which materiel items can substitute for other items, given time for transfer of components and travel. The entries in these matrices reflect the cost for making the indicated substitution. These costs are commonly expressed in units of time, although other units of measurement such as money may be used in an analysis.

A substitution which is allowed must satisfy two conditions:

(1)   The substitution is feasible; i.e., it can satisfy task accomplishment, and

(2)   The substitution is reasonable; i.e., it can be accomplished in the combat environment and would be cc idered as an alternative.

The Personnel Transfer Matrix is shown in Table 3-5 and the Materiel Transfer Matrix in Table 3-6. The twenty-five skills present in the howitzer battery organization are listed in rows down the left side of the Personnel Transfer Matrix and in columns across the top of the matrix. The diagonal containing zeros running from the upper left of each matrix to the lower right shows that each skill can substitute for itself with zero time delay. Dashes in the matrix indicate that the skill (or item) in that particular row cannot, or would not, substitute for the skill (or item) represented in the column. For example, the armorer in row 5 could not substitute for the first sergeant in column 2, and the first sergeant in row 2 would not (although be could) substitute for the ammo handler in column 24.

The rationale used for defining those substitutions which are determined to be feasible, along with the associated times, is as follows.

(1)   Within the same three digit Military Occupational Specialty Code (MOSC) skill group (e.g., 13B), two grade substitutions both higher and lower are permitted (e.g., E-4 for E-6 and vice versa) with time delays to permit learning depending upon the sophistication of the skill being considered (e.g., less time is required within the 13B and 36K groups than within the 13E group).

Table 3-5. Division-86 Battery Personnel Transfer Matrix

No	SKILL	CODE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	TRANS
01	BC	13E0	0	-	-	-	-	-	-	-	-	-	0	-	-	60	-	-	-	-	-	-	-	-	-	-	-	2
02	1SGT	13Y5	15	0	-	-	-	-	-	-	-	-	60	0	-	-	-	-	-	0	-	-	-	-	0	-	-	5
03	DVR	13B1	-	-	0	-	-	-	-	-	-	90	-	-	-	-	-	-	-	-	60	0	0	30	-	0	15	8
04	SPLSG	76Y4	-	30	-	0	0	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	30	0	15	8
05	ARM	76Y2	-	-	0	30	0	0	-	-	-	15	-	-	0	-	-	-	-	-	-	15	0	30	-	15	30	9
06	NBCSG	54E2	-	60	0	-	-	-	-	-	-	15	-	-	0	-	-	-	-	-	-	15	0	30	60	15	30	8
07	FSSGT	94B4	-	-	-	30	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	6
08	COOK	94B-	-	60	60	-	-	-	30	0	-	90	-	-	-	-	-	-	-	-	-	90	45	15	-	60	90	9
09	COMCH	31V3	-	-	-	-	-	-	-	-	0	-	-	-	60	-	-	-	-	-	-	-	-	120	-	-	-	2
10	WIRSP	36K-	-	-	0	-	-	-	-	-	30	0	0	0	-	-	-	-	-	-	-	-	30	-	-	45	90	8
11	PLLDR	13E0	0	-	-	-	-	-	-	-	-	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	3
12	PLSGT	13B4	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	4
13	DVR	13B1	-	-	-	-	-	-	-	-	-	90	0	0	0	0	0	-	-	-	-	-	0	30	-	0	-	8
14	FDO	13E0	60	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10	4
15	CHFDC	13E3	-	60	-	-	-	-	-	-	30	0	0	60	0	30	0	0	0	-	60	0	0	0	-	-	20	11
16	SRFDS	13E2	-	-	0	-	-	-	-	-	-	10	-	-	0	60	30	0	0	-	0	15	0	15	-	10	40	11
17	FDSP	13E1	-	-	0	-	-	-	-	-	-	20	-	-	-	-	60	30	0	-	-	30	15	30	-	20	0	10
18	CH/S	13B3	-	60	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	0	-	0	-	60	0	-	0	8
19	GUNR	13B2	-	-	0	-	-	-	-	-	-	20	60	30	0	-	-	-	-	-	0	0	0	0	0	0	0	11
20	CREW4	13B1	-	-	0	-	-	-	-	-	-	45	-	-	0	-	-	-	-	30	0	0	0	0	30	0	0	10
21	CREW3	13B1	-	-	0	-	-	-	-	-	-	90	-	30	0	-	-	-	-	-	15	0	0	0	-	0	20	8
22	AM CH	13B2	-	-	-	-	-	-	-	-	-	20	-	30	0	-	-	-	-	-	0	0	0	0	0	0	0	11
23	AM CH	13B3	-	60	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	30	0	30	0	-	0	7
24	AMMO	13B1	-	-	-	-	-	-	-	-	-	60	-	-	0	-	-	-	-	-	60	0	0	0	-	0	20	8
25	DVR	64C-	-	-	0	-	-	-	-	-	-	30	-	-	0	-	-	-	-	-	60	45	45	90	45	0	0	8
	SUBSTITUTES		3	7	13	2	1	0	1	1	2	16	5	8	13	4	3	2	2	6	9	15	15	18	9	14	18	187

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Table 3-6. Division-86 Battery Materiel Transfer Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TRANS
01 RADIO	0	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	0	-	-	-	-	2
02 TRK, 1/4T	-	0	0	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	3
03 TRK, 2 1/2T	-	0	0	-	0	-	0	0	-	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	7
04 TRLR, 1/4T	-	-	-	0	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	-	2
05 TRLR, 1 1/2T	-	-	-	0	0	-	-	0	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	0	5
06 TRLR, WTR	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
07 TRK, 1 1/4T	-	0	0	-	-	-	0	-	-	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	5
08 TRLR, 3/4T	-	-	0	-	0	-	-	0	-	-	-	-	0	0	0	-	-	-	-	-	-	-	-	-	5
09 AIMING CR	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
10 RADIO	0	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	0	-	-	-	-	2
11 TRK, 1/4T	-	0	0	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	3
12 TRK, 1 1/4T	-	0	0	-	-	-	0	-	-	-	0	0	0	-	-	0	-	-	-	-	-	-	-	-	6
13 TRK, 2 1/2T	-	-	0	-	-	-	0	-	-	-	0	0	0	-	-	0	-	-	-	-	-	-	-	0	6
14 TRLR, 1/4T	-	-	-	0	-	-	-	0	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	0	4
15 TRLR, 1 1/2T	-	-	-	-	0	-	-	0	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	0	4
16 CARR, CP	-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	0	0	0	-	-	-	-	-	-	4
17 CMPTR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	1
18 FD SET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	0	-	-	-	-	-	-	1
19 GEN SET	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	0
20 RADIO	0	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	0	-	-	-	-	2
21 CARR, 6T	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	-	-	-	0	-	0	-	3
22 SPH	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	0
23 GOER, 8T	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	0	0	2
24 TRLR, 1 1/2T	-	-	-	-	0	-	-	0	-	-	-	-	0	0	0	-	-	-	-	-	-	-	-	0	5
SUBSTITUTES	2	6	6	3	4	0	6	5	0	2	6	6	5	5	4	1	1	1	0	2	2	0	2	3	

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(2) Between different skill groups of essentially equal sophistication (13B and 36K, 94B to 36K, 94B to 13B), substitutions to one grade higher, to the same grade, one grade lower, and two grades lower are permitted with delay times of 120, 60, 30, and 15 minutes, respectively.

(3) From a skill group of greater sophistication to one of lesser sophistication (13E to 13B, 13E to 36K), substitutions to one grade higher, to the same grade, one grade lower, and two grades lower are permitted with delays of 60, 30, 15, and 0 minutes, respectively.

(4) Substitutions from one career field to another higher skill career field requiring schooling or special training are not permitted (13B to 13E, 36K to 13E, 13E to 94B).

(5) Between career fields, neither the substitution of chiefs nor the substitution for chiefs is permitted.

(6) As exceptions to the above guidelines, certain substitutions are permitted or rejected based upon the experience of those involved in the development and review of the data. For example, substitution of the supply sergeant for the first sergeant is permitted, while substitution from outside the 13B skill group for the howitzer section gunner is not permitted, regardless of grade, since the gunner is primarily a technical skill requirement.

With eight mission essential teams in the Division-86 battery, each MET represents 12.5% of the unit's capability. Therefore, degradation levels of 12.5%, 25.0%, and 37.5% are used for this analysis.

3.2.2 DSWS Firing Battery Input Data

The primary data source used to develop the personnel and materiel input data for the DSWS Firing Battery was its Operational and Organizational (O&O) Plan (1982 Draft). Although the O&O Plan is an outstanding source for description of the unit mission, concept of operation, personnel, equipment, and support and training requirements, it may not yet be available when this type analysis is begun. That absence would require research directly with the proponent of the new system to elicit the best available information to support development of input data. A current system which could be used for comparison is especially helpful in those situations.

The DSWS Firing Battery has 96 personnel organized as shown in Table 3-7. Major items of equipment authorized are shown in Table 3-8. There are eight firing units in the battery. They are normally deployed in firing platoon areas with control and support centralized in a battery support area. Platoons are further deployed such that individual self-propelled howitzers (SPHs) and their paired ammunition resupply vehicles (ARV) operate within assigned areas approximating circles 1000-1500 meters in diameter. Dispersion adequate to insure no two weapons are within a single counterfire footprint (200-300 meters in diameter) will normally be maintained although, in situations, two SPHs may be located in close proximity to each other to provide mutual support against a ground threat. In fact, current platoon procedures of positioning four howitzers in close proximity to each other might also be necessary if a ground threat were predominant.

Two developmental communications systems, the Position Location Reporting System/Joint Tactical Information Distribution System Hybrid (PJH) and the Single Channel Ground and Airborne Radio Subsystem (SINCGARS), are expected to be available to support the bulk of the DSWS communications requirements. The PJH will be a secure, jam-resistant digital communications system capable of providing its user with location, navigation and other features, as well as digital communications. SINCGARS is the new family of VHF-FM tactical radios that will replace the current AN/VRC-12 series and AN/PRC-77 radios. The DSWS battalion communicates internally via SINCGARS and PJH to the battery, platoon, and fire unit level. Although wire is available, it is extremely limited in capability due to anticipated distances involved and the dynamics of tactical situations. Wire would therefore be used almost exclusively within headquarters, TOC, and support areas.

The Battery Operations Center (BOC) functions as both a tactical and support/sustainment control element. BOC functions include monitoring firing unit location and status, coordinating battery and platoon position areas, coordinating maintenance and supply operations, distributing fire missions to fire units, controlling mass fires, coordinating survey, and providing back-up/supplemental technical fire control as necessary.

Table 3-7. Personnel, DSWS Firing Battery

Section	Skill	Rank/Grade	MOS	No.
BTRY HQS	BTRY CDR	CPT	13E00	1
	FIRST SGT	E-8	13Y5M	1
	DR/RTO	E-3	13B10	1
BTRY OPNS	BTRY XO	LT	13E00	1
	OPNS NCO	E-6	13E30	1
	SR FD SP	E-5	13E20	1
	NBC NCO	E-5	54E20	1
	FD SP	E-4	13E10	2
	DR/RTO	E-3	13E10	1
SPT PLT	PLT SGT	E-7	13B40	1
	VEH DR	E-3	13B10	1
	FOOD SVC SGT	E-7	94B40	1
	1ST COOK	E-5	94B20	1
	COOK	E-4/3	94B10	4
	SPLY SGT	E-6	76Y30	1
	ARMORER	E-5	76Y20	1
	TAC WIRE SP	E-4	36K10	2
	MAINT SGT	E-7	63D40	1
	SP FA AUTO MECH	E-6	63D30	1
	FA WPNS MECH	E-5	45D20	1
	PLL CLK	E-5	76C20	1
	EQ MAINT CLK	E-4	76C10	1
	FA WPNS MECH	E-4	45D10	1
	PWR GEN/WV MECH	E-4	63B10	1
	SP FA AUTO MECH	E-3	63D10	1
2-FIRE PLT	PLT LDR	LT	13E00	2
	PLT SGT	E-7	13B40	2
	GUNN SGT	E-7	13B40	2
	DR/RTO	E-3	13B10	4
8-FIRE UNITS	GUN CH	E-6	13B30	8
	ARV CH	E-5	13B20	8
	GUNNER	E-5	13B20	8
	ARV DR/CANN	E-4	13B10	8
	ASST GUN	E-4	13B10	8
	SPH DR/CANN	E-4	13B10	8
	CANN/AMMO HDLR	E-3	13B10	8

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Table 3-8. Materiel, DSWS Firing Battery

Section	Description	No.
BTRY HQS	TRK, 1 1/4 ton, HMMWV	1
BTRY OPNS	BOCV (BOC Vehicle)	1
SPT PLT	TRK, 1 1/4 ton, HMMWV	2
	TRK, 2 1/2 ton	3
	MFKT (Mobile Field Kitchen Trailer)	1
	AMV (Armored Maintenance Vehicle)	1
	TRLR, 3/4 ton	1
	TRLR, Water	1
2-FIRE PLT	TRK, 1 1/4 ton, HMMWV	4
8-FIRE UNITS	SPH (Self-Propelled Howitzer)	8
	ARV (Ammunition Resupply Vehicle)	8

The Battery Support Platoon provides food service, supply, communication, and maintenance support.

The METs for the DSWS firing battery are very similar to those developed for the Division-86 howitzer battery. The personnel METs are shown in Table 3-9 and the materiel METs in Table 3-10. The following subparagraphs summarize the rationale for the composition of those METs.

(1) The first firing unit includes a Self-Propelled Howitzer (SPH) and its paired Ammunition Resupply Vehicle (ARV). There is a need for tactical command and control, since the SPH can operate independent-ly, that is provided by the Battery Operations Center (BOC) with the battery Executive Officer, the Operations NCO, and two Fire Direction Specialists. The BOC also provides backup technical control. SP automotive and FA maintenance support is also added along with the Armored Maintenance Vehicle (AMV).

(2) With the addition of the second firing unit, it is necessary to add a Platoon Leader, Platoon Sergeant, and driver.

(3) The third firing unit required no additional support.

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Table 3-9. DSWS Battery Personnel METs

				MET STRUCTURE					
		TM1	TM2	TM3	TM4	TM5	TM6	TM7	TM8
01	BC	-	-	-	-	1	-	-	-
02	1 SGT	-	-	-	-	1	-	-	-
03	DR/RTO	-	-	-	-	1	-	-	-
04	XO	1	-	-	-	-	-	-	-
05	OPS NCO	1	-	-	-	-	-	-	-
06	SR FD SP	-	-	-	-	-	-	-	-
07	FD SP	2	-	-	-	-	-	-	-
08	NBC NCO	-	-	-	-	-	-	-	-
09	SPT PLSGT	-	-	-	-	-	-	1	-
10	DVR	-	-	-	-	-	-	1	-
11	FS SGT	-	-	-	-	-	-	-	-
12	COOK	-	-	-	-	-	-	-	-
13	SPL SGT	-	-	-	-	-	-	-	-
14	ARM	-	-	-	-	-	-	-	-
15	WIR SP	-	-	-	-	1	-	-	-
16	MT SGT	-	-	-	1	-	-	-	-
17	SP MECH	1	-	-	-	-	-	-	-
18	FA MECH	1	-	-	-	-	-	-	-
19	PLL/EQ	-	-	-	1	-	-	-	-
20	WV MECH	-	-	-	1	-	-	-	-
21	PLTLDR	-	1	-	-	-	1	-	-
22	PLTSGT	-	1	-	1	-	1	-	1
23	DR/RTO	-	1	-	1	-	1	-	1
24	GUN CH	1	1	1	1	1	1	1	1
25	ARV CH	1	1	1	1	1	1	1	1
26	GUNR	1	1	1	1	1	1	1	1
27	CREW	4	4	4	4	4	4	4	4
	TOTAL	13	10	7	12	11	10	9	9
	CUMULATIVE	13	23	30	42	53	63	72	81

Table 3-10. DWSW Battery Materiel METs

		MET STRUCTURE							
		TM1	TM2	TM3	TM4	TM5	TM6	TM7	TM8
01	HMMWV	-	-	-	-	1	-	-	-
02	BOCV	1	-	-	-	-	-	-	-
03	HMMWV	-	-	-	-	1	-	1	-
04	TRK, 2 1/2 T	-	-	-	1	-	-	-	-
05	MFKT	-	-	-	-	-	-	-	-
06	AMV	1	-	-	-	-	-	-	-
07	TRLR, 3/4 T	-	-	-	-	-	-	-	-
08	TRLR, WTR	-	-	-	-	-	-	-	-
09	HMMWV	-	1	-	1	-	1	-	1
10	SPH	1	1	1	1	1	1	1	1
11	ARV	1	1	1	1	1	1	1	1

(4) With the fourth firing unit, the Gunnery Sergeant and driver are added so that the increased coverage of firing units can be supervised. The maintenance supervisor, PLL clerk, and wheeled vehicle mechanic are also added to provide increased coverage.

(5) The Battery Commander, First Sergeant, driver, and a wireman are added with the fifth firing unit since the span of control capability of the first Platoon Leader is exceeded.

(6) The second Platoon Leader, Platoon Sergeant, and driver are added with the sixth firing unit when splitting the battery into two 3-gun platoons becomes a possibility.

(7) Along with the seventh firing unit, the Support Platoon Sergeant and his driver are added to assist the First Sergeant in supervising all support activities.

(8) A second Gunnery Sergeant and driver are added with the eighth firing unit to provide sufficient supervision to the widely dispersed operations.

The next step is to prepare transfer matrices for the firing battery personnel and key materiel. The same concepts are used as described earlier for the M109 battery. Since the skill requirements for the DSWS unit were explicitly identified and the MOSs were essentially the same, except for the addition of maintenance skills, the transfer matrices were kept as similar as possible. The only significant change is the increased time penalty for many of the substitutions which reflects a travel time between the BOC and the widely dispersed firing units. That change did not effect the feasibility or reasonableness of substitutions. The Personnel Transfer Matrix is shown in Table 3-11 and the Materiel Transfer Matrix in Table 3-12.

With eight mission essential teams in the DSWS battery, each MET represents 12.5% of the unit's capability. Therefore, degradation levels of 12.5%, 25.0%, and 37.5% are used for this analysis.

3.2.3 Div-86 Howitzer Battery Capability Analysis

The AMORE methodology was applied to determine the maximum capability which the Division-86 howitzer battery could achieve following the application of 12.5%, 25.0%, and 37.5% degradation. The results for personnel are shown in Figure 3-1.

The solid diagonal ("efficient balance") line in Figure 3-1 is a reference line showing balance between resources and capability. It represents the unit response corresponding to a decrease in capability which is equal to the level of degradation, e.g., a 20% level of degradation would result in a 20% decrease in capability. Data points on or above that line generally indicate a population limited unit while points below the line generally indicate a skill limited unit.

At 12.5% degradation, the expected number of unit survivors is 112.9 [129 x (1-.125) = 112.9] and the cumulative requirement for the 7th MET (i.e., sum of the requirements of the first seven METs) is 104. Thus, on the average, there is a substantial surplus of available personnel to meet the requirement for seven teams. The analysis shows that the unit was always able

Table 3-11. DSWS Battery Personnel Transfer Matrix

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	TRANS
01	BC	13E0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	2
02	1SGT	13Y5	15	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	30	-	30	-	-	-	5
03	DR/RTO	13B1	-	-	0	-	-	-	-	-	-	0	-	-	-	-	90	-	-	-	-	-	-	-	30	-	90	60	30	6
04	XO	13E0	0	-	-	0	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	3
05	OPSNCO	13E3	-	30	-	30	0	0	0	-	0	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
06	SRFDSP	13E2	-	-	30	90	30	0	0	-	-	30	-	-	-	-	30	-	-	-	-	-	-	-	30	-	45	-	30	9
07	FDSP	13E1	-	-	30	-	60	15	0	0	-	30	-	-	-	-	30	-	-	-	-	-	-	-	30	-	90	-	30	8
08	NBCNCO	54E2	-	-	0	-	-	-	-	0	-	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	6
09	SPLTSG	13B4	-	0	-	-	-	-	-	-	0	0	-	-	-	-	15	-	-	-	-	-	45	30	30	30	45	60	30	5
10	DR	13B1	-	-	0	-	-	-	-	-	-	0	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
11	FSSGT	94B4	-	60	-	-	-	-	-	-	30	60	-	-	-	-	60	-	-	-	-	-	-	-	90	-	90	-	90	5
12	COOK	94B-	-	-	60	-	-	-	-	-	-	-	0	0	-	-	90	-	-	-	-	-	-	-	-	-	-	-	-	6
13	SPLSGT	76Y3	-	30	-	-	-	-	-	-	30	-	0	-	30	0	0	-	-	-	15	-	-	-	30	-	90	-	60	7
14	ARM	76Y2	-	-	-	-	-	-	-	-	-	-	-	-	0	0	15	-	-	-	30	-	-	-	-	-	-	-	-	8
15	WIRSP	36K1	-	-	0	-	-	-	-	-	-	0	-	-	-	-	0	0	90	-	-	-	-	-	30	-	90	-	90	4
16	MTSGT	63D4	-	60	-	-	-	-	-	-	45	15	-	-	-	-	-	0	0	0	0	0	-	-	-	-	-	-	-	6
17	SPMECH	63D-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	90	15	0	-	-	-	-	-	-	90	5
18	FAMECH	45D-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75	90	0	15	60	-	-	-	-	-	-	90	5
19	PLL/EQ	76C-	-	-	15	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
20	WVMECH	63B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	90	15	0	-	-	-	-	-	-	90	4
21	PLTLDR	13E0	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	0	-	-	-	4
22	PLTSGT	13B4	-	60	-	-	30	-	-	-	30	30	-	-	-	-	30	-	-	-	-	-	0	0	-	-	45	-	0	5
23	DR/RTO	13B1	-	-	30	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	-	0	6
24	GUNCH	13B5	-	90	-	-	-	-	-	-	45	30	-	-	-	-	-	-	-	-	-	-	60	-	-	0	0	60	0	7
25	ARVCH	13B2	-	-	30	-	-	-	-	-	90	30	-	-	-	-	-	-	-	-	-	-	-	30	-	0	0	0	0	8
26	GUNR	13B2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	30	0	0	4
27	CREW	13B1	-	-	45	-	-	-	-	-	-	45	-	-	-	-	30	-	-	-	-	-	-	15	15	-	30	45	0	6
	SUBSTITUTES		3	7	11	4	4	2	2	0	7	11	1	1	2	1	10	2	3	3	6	3	6	6	10	5	12	8	17	147

Table 3-12. DSWS Battery Materiel Transfer Matrix

		01	02	03	04	05	06	07	08	09	10	11	TRANS
01	HMMWV	0	-	0	0	-	-	-	-	30	-	-	3
02	BOCV	-	0	-	-	-	-	-	-	-	-	-	0
03	HMMWV	0	-	0	-	-	-	-	-	30	-	-	2
04	TRK, 2 1/2 T	0	-	0	0	0	0	-	-	30	-	30	6
05	MFKT	-	-	-	-	0	-	-	-	-	-	-	0
06	AMV	-	-	-	-	-	0	-	-	-	-	-	0
07	TRLR, 3/4 T	-	-	-	-	-	-	0	-	-	-	-	0
08	TRLR, WTR	-	-	-	-	-	-	-	0	-	-	-	0
09	HMMWV	30	-	30	30	-	-	-	-	0	-	-	3
10	SPH	-	-	-	-	-	-	-	-	-	0	-	0
11	ARV	-	-	-	30	-	-	-	-	-	-	0	1
SUBSTITUTES		3	0	3	3	1	1	0	0	3	0	1	15

to form seven or more METs (87.5% capability) at that level of degradation; thus, there are no critical or limiting skills at that level.

At 25% degradation, the expected number of unit survivors is 96.75 and the cumulative requirement for the 6th MET is 92. Although the expected strength is still greater than the requirement, the magnitude of that difference is much smaller now. The output data reveals that the unit is able to form six or more METs on 27 of the 30 replications. For the three replications which failed, the needed skills can be identified. There are a total of nine different skill lines (#2, 9, 10, 11, 12, 15, 16, 20, and 21) representing a total of 17 personnel which are needed and not available in the three failed replications. Of the 17 personnel needed, six are crewmen which

3-20
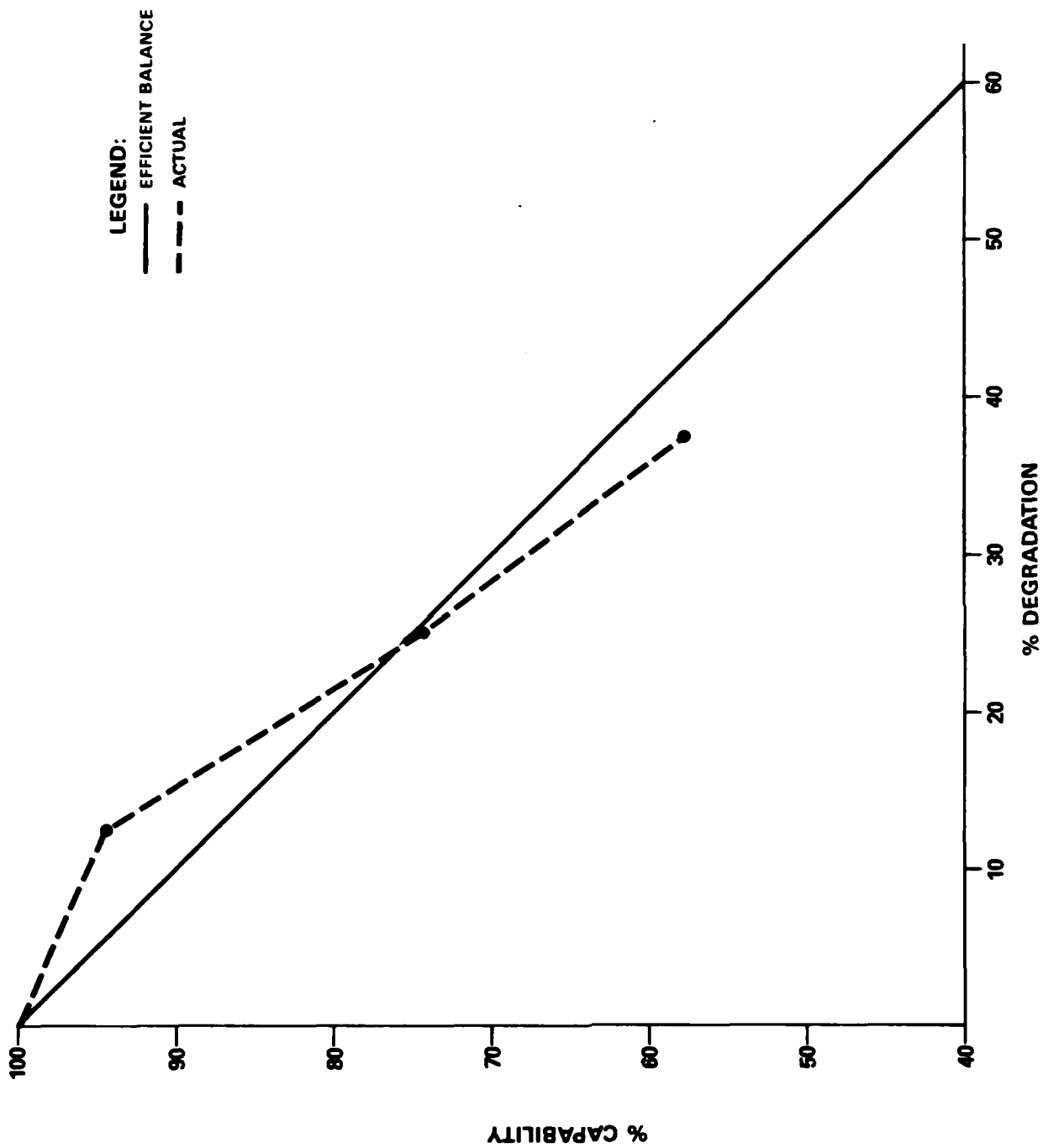
FIGURE 3-1. CAPABILITY VS. DEGRADATION, DIVISION-86 HOWITZER BATTERY

indicates population limitations, but five represent senior leadership, two are communication skills, and four are fire direction skills. Although none of these are dominating, they are limiting skills needing improvement.

At 37.5% degradation, the expected number of unit survivors is 80.6 and the cumulative requirement for the 5th MET is 76. This difference is about the same magnitude as the previous case. Based upon the output data, the unit is not resilient at this level. The unit is able to form five or more METs on 24 of the 30 replications. On two of these six failures, it could not form even the first MET. There are ten different skill lines (#1, 2, 9, 10, 14, 15, 16, 17, 18, and 21) representing a total of 22 personnel which are needed but not available in the six failing replications. Only four of those needed personnel are crewmen this time. Other skill requirements are for eight fire direction, four communication, and six senior leadership personnel. Again no skills are dominating, but it is clear that the fire direction (13E) and communication (31V and 36K) skills are the most limiting in the unit, and are apparently critical skills.

Tentative conclusions about the Division-86 howitzer battery are that fire direction (13E) and communication (31V and 36K) are critical skills at 37.5% degradation, and thus offer the greatest potential payoff from changed requirements. Limiting skills are those in the senior leadership category.

3.2.4 DSWS Firing Battery Capability Analysis

The AMORE methodology was applied to determine the maximum capability which the DSWS firing battery could achieve following the application of 12.5%, 25.0%, and 37.5% degradation. The results for personnel are shown in Figure 3-2.

At 12.5% degradation, the expected number of unit survivors is 84 [96 x (1-.125) = 84] and the cumulative requirement for the 7th MET is 72. Thus, on the average, there is a substantial surplus of available personnel to meet the requirement for seven teams. Only one time was the unit unable to form seven
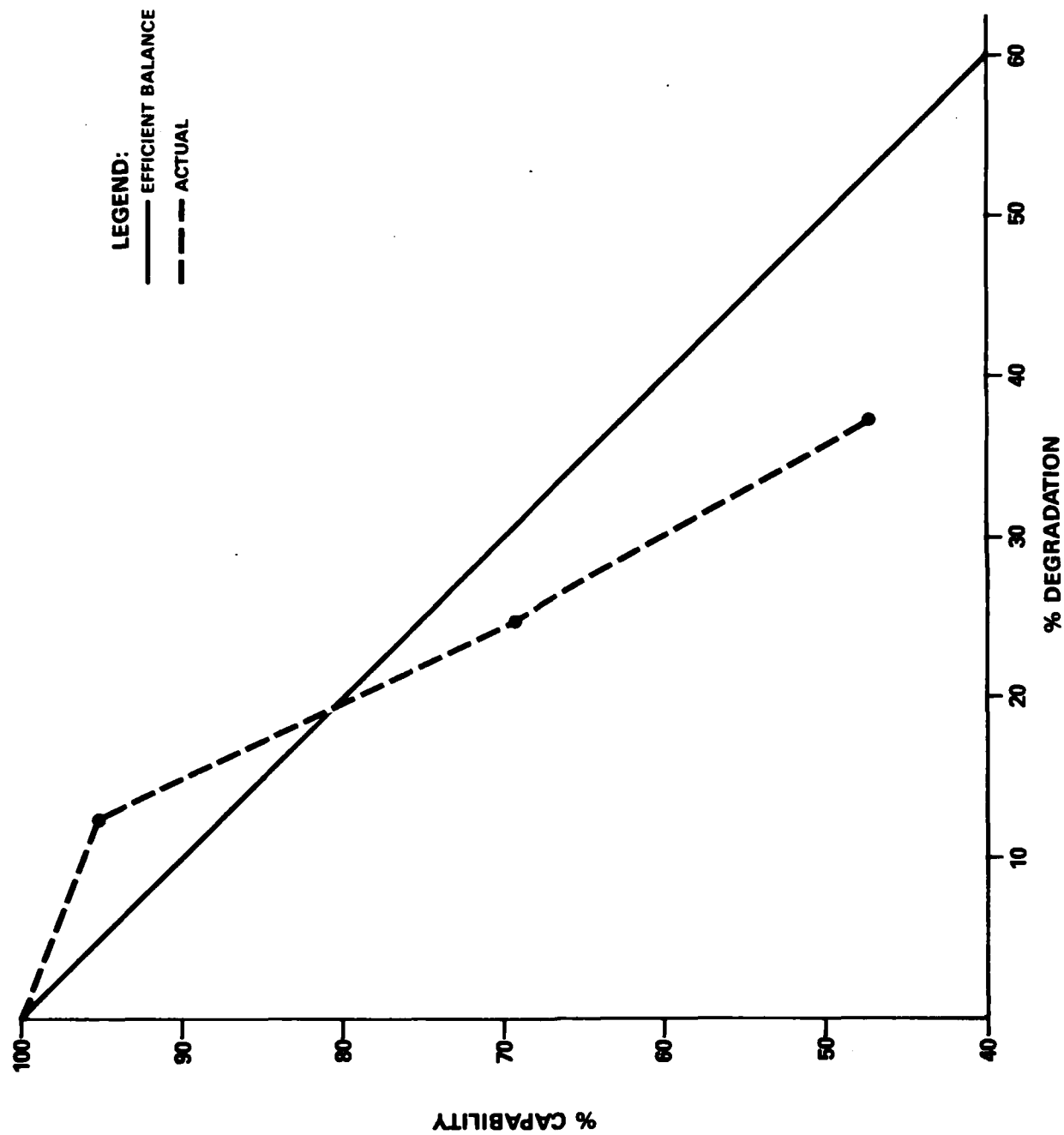
FIGURE 3-2. CAPABILITY VS. DEGRADATION, DSWS FIRING BATTERY

or more METs (87.5% capability) at that level of degradation. The limiting skill in that one case was the SP Auto Mechanic (63D).

At 25% degradation, the expected number of unit survivors is 72 and the cumulative requirement for the 6th MET is 63. This still leaves a reasonable surplus of strength in the unit. Based upon the output data, the unit is not resilient at this level. The unit is able to form six or more METs on 21 of the 30 replications. There were four different skills which were needed on those nine failed replications. They represented a total of 11 personnel which were needed and not available in the nine trials. Again, these critical skills are all maintenance skills: the Maintenance Sergeant (63D), SP Auto Mechanic (63D), FA Weapons Mechanic (45D), and the Power Generator/Wheeled Vehicle Mechanic (63B).

At 37.5% degradation, the expected number of unit survivors is 60 and the cumulative requirement for the 5th MET is 53. Output data reveals that this time the unit is able to form five or more METs on only 13 of the 30 replications, and the unit is not resilient. On three of the 17 failures, not even the first MET could be formed. There were ten different skill lines (#1, 4, 5, 7, 16, 17, 18, 20, 21, and 22) representing a total of 33 personnel which are needed but not available in the 17 failed replications. None of these personnel needs are weapon crewmen (13B) although seven are senior leadership (officers and senior NCO's). There are 22 personnel needs in maintenance skills (63D, 45D, and 63B) and four in fire direction skills (13E). The maintenance skills are critical by their consistent shortfall and are primarily responsible for the unit capability response falling so far below the equal balance line.

Tentative conclusions about the DSWS firing battery are that maintenance, senior leadership, and fire direction (13E) skills are critical skills and should be examined more closely. The unit's capability response to degradation is now available for comparison in subsequent analyses, and critical and limiting skills have been identified.

3.3 DSWS FIRING BATTERY DESIGN ANALYSIS

The purpose of this step is to identify the relative leverage of the DSWS Firing Battery skill groups for improving unit resiliency. The approach is to adjust the personnel skill allocations of the battery so as to satisfy unit resiliency design criteria with minimum personnel resources.

A streamlined version of the AMORE Unit Design Methodology [Hannon, Robinson, and Stenstrom, 1983] has been adapted for this application in order to accomplish the stated purpose of this step. A summarized version of the DSWS Firing Battery design analysis follows in this section with a more detailed explanation, along with necessary tables and blank forms, in Appendix C.

The METs and Transfer Matrix needed for this analysis are part of the Step 1 input data (Tables 3-9 and 3-11, respectively). They were developed based upon a selected mission, so it should be realized that the same mission is being used as the basis for this analysis. For this example, the mission is stated as "sustained operations" which implies a variety of tactical operations over a sustained period (more than 72 hours).

3.3.1 Design Criteria

The design criteria for the DSWS Firing Battery are established as:

- mission - sustained operations
- design goal - 6 METs
- level of degradation - 25%
- level of assurance - 90%
- undegraded goal - 8 METs

This means the unit is being designed to be resilient until at least the 25% level of degradation which is a mid-range point for the earlier baseline analysis. Since being able to form six of the eight METs is equivalent to 75% capability, six teams (METs) are selected as the design goal level. Note that

if six teams can be formed, the unit capability is equal to the level of unit survivors (75%) which means the unit is resilient.

The assurance selected for the design is 90%. This is the level of confidence which may be placed on the ability of the final design to meet the design goal team level. This assurance is achieved by requiring that in 90% of the AMORE iterations, the design team goal (6 METs) or more must be reconstituted. The undegraded goal is the number of METs the unit must be able to form when no degradation occurs. In this case, it is the total number of METs in the unit.

3.3.2 Substitutability Factors

The substitutability factors may be obtained directly from Table 3-11 which is the DSWS Battery Personnel Transfer Matrix. A completed Design Form 2P is shown at Figure 3-3 with both substitutability factors listed for each skill. Columns 1-4 are identifying information for each skill. Column 5 lists the cumulative requirements for each skill for the first six teams (the Design Goal).

Column 6 is substitutability factor (1), the number of substitutes possible into each skill. The values in the bottom line (labeled "substitutes") of Table 3-11 are the number of entries in each column (not counting the "0's" on the principal diagonal) and equate to factor (1). These values are placed in column 6 of Figure 3-3.

Column 7 is substitutability factor (2), the number of substitutions possible from a skill into all other skills. The values in the right-hand column (labeled "trans") of Table 3-11 are the number of entries in each row (not counting the "0's" on the principal diagonal) and equate to factor (2). These values are placed in column 7 of Figure 3-3.

3.3.3 Add-Ons

The minimum number of personnel necessary to be added to the design goal MET in order to achieve design criteria is determined to be 21. In order to

1	2	3	4	5	6	7	8	9
					TRANSFERS POSSIBLE INTO THIS	TRANSFERS POSSIBLE FROM THIS	~~ZERO/ZERO~~ ~~ADD ONE~~	
LINE NUMBER	SKILL NAME	GRADE	MOSC	DESIGN GOAL TEAM _6_	SKILL, IF RQD	SKILL, IF AVAIL	~~(FENCED)~~	REMARKS
1	BC	CPT	13E0	1	3	2		
2	1SGT	E8	13Y5	1	7	5		
3	DVR	E3	13B1	1	11	6		
4	XO	LT	13E0	1	4	3		
5	OPS NCO	E6	13E3	1	3	4		
6	SR FD	E5	13E2	0	2	9		
7	FD SP	E4/3	13E1	2	2	8		
8	NBC NCO	E5	54E2	0	0	6		
9	SPT PS	E7	13B4	0	7	5		
10	DVR	E3	13B1	0	11	6		
11	FS SGT	E7	94B4	0	1	5		
12	COOK	E5/3	94B2/1	0	1	6		
13	SPLY	E6	76Y3	0	2	7		
14	ARM	E5	76Y2	0	1	8		
15	WIRSP	E4	36K1	1	10	4		
16	MT SGT	E7	63D4	1	2	6		
17	SP MECH	E6/3	63D3/1	1	3	5		
18	FA MECH	E5/4	45D2/1	1	3	5		
19	PLL/EQ	E5/4	76C2/1	1	6	3		
20	WV MECH	E5/4	63B1	1	3	4		
21	PLDR	LT	13E0	2	6	4		
22	P SGT	E7	13B4	3	6	5		

FIGURE 3-3.   DESIGN FORM 2P — PERSONNEL

1	2	3	4	5	6	7	8	9
					TRANSFERS POSSIBLE INTO THIS SKILL, IF RQD	TRANSFERS POSSIBLE FROM THIS SKILL, IF AVAIL	~~ZERO/ZERO~~ ~~ADD-ONE~~ ~~(FENCED)~~	
LINE NUMBER	SKILL NAME	GRADE	MOSC	DESIGN GOAL TEAM _6_				REMARKS
23	DVR	E3	13B1	3	10	6		
24	GUN CH	E6	13B3	6	5	7		
25	ARI CH	E5	13B2	6	12	8		
26	GUNR	E5	13B2	6	8	4		
27	CREW	E4/3	13B1	24	17	6		
TOTAL				63				

FIGURE 3-3. DESIGN FORM 2P — PERSONNEL (CONTINUED)

account for variability extremes, 64 more personnel (total of 85 add-ons) are needed to determine a maximum number necessary to meet the design criteria. The mid-point of these two bounds is a total add-on of 53 personnel (21 + 32). See paragraph C.1.2 for details on how these calculations are made.

The numbers 21, 53, and 85 are the sizes of the lower, middle, and upper bound add-ons respectively. Personnel skills will now be identified and pri- oritized to achieve these add-ons. The bounds will be split sequentially until a best solution is identified.

3.3.4 Priorities for Add-Ons

Skill groups are assigned priority for receiving add-ons based upon the greatest need which is identified by substitutability factor (1). Thus, based upon the values in column 6 of Figure 3-3, highest priority is assigned to the line with the smallest value for a skill which is included in the design goal MET (i.e., a line whose value in column 5 is not zero). In this example, both lines #7 and #16 have the smallest value, 2. As a tie breaker, select the skill which also has the smallest value in column 7. Based upon these rules, the ten highest priority skill groups for add-ons are (Figure 3-3) #16, 7, 1, 17, 18, 20, 5, 4, 24, and 21.

These priorities are now applied by assigning available skill add-ons. Figure 3-4 contains a completed Design Form 4 with a record of which skills were added-on to form the lower bound, middle bound, and upper bound. Column 23 shows which skill was selected for add-on in each case. To determine that selection, acceptable skills are identified based upon their availability (limits are set on how many of each type skill may be added) and their substi- tutability (they must be able to substitute for the required skill). The acceptable skill actually selected is then based upon substitutability factor (2), i.e., the number of substitutions which are possible from it into other skills. The acceptable skill with the largest factor (2) value is selected.

Column 24 indicates how many of each skill were added, and column 25 is a cumulative count of the add-ons. The lower bound is achieved by the 14 add-

21	22	23	24	25
PRIORITY NUMBER	LINE NUMBER REQUIRED	LINE NUMBER ASSIGNED	FINAL ADD ONS (INCLUDING COLUMN 8)	REMARKS (CUMULATIVE)
1	16	17	1	1
2	7	6	1	2
3	1	4	1	3
4	17	17	1	4
5	18	18	1	5
6	20	18	1	6
7	5	6	1	7
8	4	5	1	8
9	24	25	2	10
10	21	24	1	11
11	22	24	1	12
12	19	14	1	13
13	2	13	1	14	(+ 7 "SPECIAL" SKILLS = 21)
2	7	7	2	16
4	17	20	1	17
5	18	20	1	18
7	5	7	1	19
9	24	9	1	20
9	24	22	1	21
9	24	26	2	23
12	19	19	1	24
13	2	11	1	25

LOWER BOUND (arrow to row 13)

FIGURE 3-4.   DESIGN FORM 4 — PRIORITIZATION LISTING

21	22	23	24	25
PRIORITY NUMBER	LINE NUMBER REQUIRED	LINE NUMBER ASSIGNED	FINAL ADD ONS (INCLUDING COLUMN 8)	REMARKS (CUMULATIVE)
14	26	3	1	26
14	26	10	1	27
14	26	23	1	28
14	26	27	5	33
15	15	8	1	34
15	15	12	1	35
16	23	12	4	39
17	3	27	2	41
18	25	27	8	49
19	27	27	4	53
19	27	27	21	74
19	27	15	1	75

MIDDLE BOUND ← (points to row: 19 27 27 4 53)

UPPER BOUND ← (points to row: 19 27 15 1 75)

FIGURE 3-4. DESIGN FORM 4 — PRIORITIZATION LISTING (CONTINUED)

ons listed plus seven personnel who are not part of the METs, but whose pres-
ence in a final unit design is deemed essential for peacetime support and
extended operations. These seven personnel are the NBC NCO (#8), the Food
Service Sergeant (#11), and five Cooks (#12). Since the seven special add-ons
are part of the later prioritized add-ons, similar special add-ons are not
needed for the middle or upper bounds.

3.3.5 Optimum Design

The list in Figure 3-4 is a guideline to determine which skills to add to
the basic unit MET requirements in order to achieve a given unit design. The
initial strength bounds are successively split, based upon the results of se-
quential AMORE calculations of capability, until the minimal resources neces-
sary to achieve the design criteria are identified. Since 30 replications are
made for each case, the criteria for success is when six or more teams can be
formed on 27 or more of the replications. The objective is to find the mini-
mal design which meets that test criteria.

Figure 3-5 contains a completed Design Form 5 showing the record of all
cases tried and the results. The various cases are listed in columns 28
through 35. The number shown at the top of the columns (i.e., 21, 53, 85...)
indicate the total number of add-ons for that case. The circled values in the
columns indicate skill strengths different from the design goal strength which
is shown in column 27. The values in the middle of page 3-34, under "RESULTS
OF AMORE ITERATIONS", indicate the number of teams which could be formed in
each of the 30 iterations. For example, case 21 (lower bound) fails because
six or more teams can be formed on only 20 of the 30 iterations. Case 29 suc-
ceeds with 28 of the iterations forming six or more teams.

Case 27 succeeds exactly (27 of the 30 iterations) while Case 26, with
one less add-on, fails with six or more teams able to be formed on only 25 of
the 30 iterations. Thus case 27 is tentatively selected as the optimum de-
sign. That design is then tested to insure it can form all METs with zero
degradation. The tentative design is successful at zero degradation so it is
selected as the final design.

DESIGN FORM 5 - AMORE INITIAL STRENGTH ENTRY - (PERSONNEL) OR MATERIEL (CIRCLE ONE)
CASE __1__   UNIT DS4JS FB   PAGE 1 OF 2   DATE 1 FEB. 84

26 LINE NUMBER	27 DESIGN GOAL STRENGTH (COLUMN 5)	28 LOWER BOUND CASE 21 MAKE/FAIL?	29 MIDDLE BOUND CASE 53 MAKE/FAIL?	30 UPPER BOUND CASE 85 MAKE/FAIL?	31 CASE 37 MAKE/FAIL?	32 CASE 29 MAKE/FAIL?	33 CASE 25 MAKE/FAIL?	34 CASE 27 MAKE/FAIL?	35 CASE 26 MAKE/FAIL?	36 CASE ___ MAKE/FAIL?
1	1	1	1	1	1	1	1	1	1	
2	1	1	1	1	1	1	1	1	1	
3	1	1	(2)	(2)	(2)	1	1	1	1	
4	1	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	
5	1	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	
6	0	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	
7	2	2	(5)	(5)	(5)	(5)	(4)	(5)	(5)	
8	0	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
9	0	0	(1)	(1)	(1)	(1)	0	(1)	0	
10	0	0	(1)	(1)	(1)	0	0	0	0	
11	0	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
12	0	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	
13	0	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
14	0	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
15	1	1	1	(2)	1	1	1	1	1	
16	1	1	1	1	1	1	1	1	1	
17	1	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	
18	1	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	
19	1	1	(2)	(2)	(2)	1	1	1	1	
20	1	1	(3)	(3)	(3)	(3)	(3)	(3)	(3)	
21	2	2	2	2	2	2	2	2	2	
22	3	3	(4)	(4)	(4)	(4)	3	3	3	

FIGURE 3-5.   DESIGN FORM 5 — AMORE INITIAL STRENGTH ENTRY

DESIGN FORM 5 - AMORE INITIAL STRENGTH ENTRY - (PERSONNEL) OR MATERIEL (CIRCLE ONE)
CASE __1__   UNIT DS&S FB   PAGE 2 of 2   DATE 1 FEB 84

26	27	28	29	30	31	32	33	34	35	36
	DESIGN GOAL STRENGTH	LOWER BOUND CASE 21	MIDDLE BOUND CASE 53	UPPER BOUND CASE 85	CASE 37	CASE 29	CASE 25	CASE 27	CASE 26	CASE
LINE NUMBER	(COLUMN 5)	MAKE/(FAIL)?	(MAKE)/FAIL?	MAKE/FAIL?	(MAKE)/FAIL?	(MAKE)/FAIL?	MAKE/(FAIL)?	(MAKE)/FAIL?	MAKE/(FAIL)?	MAKE/FAIL?
23	3	3	④	④	④	3	3	3	3	
24	6	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	
25	6	⑧	⑧	⑧	⑧	⑧	⑧	⑧	⑧	
26	6	6	⑧	⑧	⑧	⑦	6	6	6	
27	24	24	㊸	㊽	㉗	24	24	24	24	
TOTAL	63	84	116	148	100	92	88	90	89	

RESULTS OF AMORE ITERATIONS (30 EACH)

	27	28	29	30	31	32	33	34	35	36
TEAM	8	28	—		2					
	7	2	—		23	4	2	6	2	
DESIGN GOAL →	6	20	—		5	24	21	21	23	
	5	9	—			2	7	3	5	
	4		—							
	3	1	—							
	2		—							
	1		—							
	0		—							

FIGURE 3-5.   DESIGN FORM 5 — AMORE INITIAL STRENGTH ENTRY (CONTINUED)

The new design is shown in the right hand column of Table 3-13. The design shown is not adjusted to show revised duty positions, but is just intended to show the new skill requirements. The final test described in the preceeding paragraph verifies that these skill authorizations can substitute to fill all MET requirements.

The effect of these unit design changes on unit capability as a function of degradation can be seen in Figure 3-6. The "actual" line shown is the unit response calculated earlier as the baseline response and shown in Figure 3-2. The "design" line shown is the corresponding response from this new design. This new response curve is better than the actual design, and requires less personnel.

The analysis does indicate that savings in MOS 13E skill positions may be counterproductive. The increased presence of that MOS in this new unit design is not a consequence of increased requirements, but of that skill's exceptional capability to substitute for a variety of other skill positions. Thus, as the MOS 13E authorization of a firing battery increases, its substitutability increases which has a positive impact on the battery's capability response to degradation.

Based on this analysis, there is potential to further reduce the actual MOS 13B authorizations if increased personnel flexibility is attained from the addition of a few MOS 13E authorizations. In fact, the design results would have been even more pronounced if the MOS 13E increases had not been constrained by the analyst to fairly tight traditional bounds.

3.4 SYSTEM DESIGN ALTERNATIVES

The purpose of this step is to identify specific alternatives to the materiel system design which should be analyzed for their manpower, personnel, and training impact. These potential impacts are analyzed in depth in the following step (paragraph 3.5) of this application.

At this point, a detailed analysis could be performed on the system functional requirements and the resulting operator and maintainer task require-

Table 3-13. Personnel, DSWS Unit Design

Section	Skill	Rank/Grade	MOS	Now	New
BTRY	BTRY CDR	CPT	13E00	1	1
	FIRST SGT	E-8	13Y5M	1	1
	DR/RTO	E-3	13B10	1	1
BTRY OPNS	BTRY XO	LT	13E00	1	2
	OPNS NCO	E-6	13E30	1	2
	SR FD SP	E-5	13E20	1	2
	NBC NCO	E-5	54E2^	1	1
	FD SP	E-4	13E10	2	4
	DR/RTO	E-3	13E10	1	1
SPT PLT	PLT SGT	E-7	13B40	1	1
	VEH DR	E-3	13B10	1	0
	FOOD SVC SGT	E-7	94B40	1	1
	1ST COOK	E-5	94B20	1	1
	COOK	E-4/3	94B10	4	4
	SPLY SGT	E-6	76Y30	1	1
	ARMORER	E-5	76Y20	1	1
	TAC WIRE SP	E-4	36K10	2	1
	MAINT SGT	E-7	63D40	1	1
	SP FA AUTO MECH	E-6	63D30	1	1
	FA WPNS MECH	E-5	45D20	1	1
	PLL CLK	E-5	76C20	1	1
	EQ MAINT CLK	E-4	76C10	1	0
	FA WPNS MECH	E-4	45D10	1	2
	PWR GEN/WV MECH	E-4	63B10	1	3
	SP FA AUTO MECH	E-3	63D10	1	2
2-FIRE PLT	PLT LDR	LT	13E00	2	2
	PLT SGT	E-7	13B40	2	2
	GUNN SGT	E-7	13B40	2	1
	DR/RTO	E-3	13B10	4	3
8-FIRE UNITS	GUN CH	E-6	13B30	8	8
	ARV CH	E-5	13B20	8	8
	GUNNER	E-5	13B20	8	6
	ARV DR/CANN	E-4	13B10	8	8
	ASST GUN	E-4	13B10	8	8
	SPH DR/CANN	E-4	13B10	8	4
	CANN/AMMO HDLR	E-3	13B10	8	4
				96	90

FIGURE 3-6. CAPABILITY VS. DEGRADATION, DSWS DESIGN CASE

LEGEND:
——— EFFICENT BALANCE
— · — · — ACTUAL
— — — DESIGN

% DEGRADATION

% CAPABILITY

ments. A task is a unit of work activity that constitutes a logical and necessary step in the performance of a required activity or event. Functional requirements analysis determines the identity and extent of the functions that the system is required to perform in combat. The purpose of such an analysis is to identify and isolate the important relationships between hardware subsystems and manpower and training requirements so that system components with the greatest leverage may be selected for subsequent impact analysis. Time and resource limitations preclude a detailed function/task analysis for this report, but the general approach used in the HARDMAN methodology is applicable for this purpose.

From the Step 1 unit baseline analyses, it is noted that the basic weapon system crewman (MOS 13B) is not critical for the DSWS firing battery and has only a minor impact on the Division-86 howitzer battery. There is generally sufficient availability and substitutability within the battery to meet those crew requirements. Senior leadership or supervisor skills (grade E-7 and above) are critical in both units. Fire direction (13E) and communication (31V and 36K) skills are critical in the Division-86 unit. Fire direction (13E) and maintenance (45D, 63B, and 63D) skills are critical in the DSWS unit. From the Step 2 unit design analysis, it is noted that artillery crewmen (13B) positions could be reduced, particularly if some fire direction (13E) positions are added (13E's are a leverage skill). Also, the communications (36K) requirement could be reduced under those conditions.

Based then upon the identification of critical skills and a leverage skill, the approach now is to identify or postulate specific changes to the materiel system design which will eliminate the task requirements of an identified critical skill or at least reduce those task requirements to a point where they could be combined with another MOS. Some possible materiel system design changes are: an automatic loader for the firing unit; a device to remotely check firing data on the firing units and prevent them from firing incorrectly; built-in maintenance diagnostic equipment with increased modular replacements for the weapon system; and improved wire communications equipment. Although it is not the intent of this report to develop those alternatives in detail, each of them will be examined to some degree for their impact on MPT requirements.

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The DSWS is already designed to have a semi-automatic or fully automatic loader with an ammunition handling system. The interest in this example then is to examine the impact of such a loader on crew requirements, since the automated loader is the primary reason that crew size in the DSWS battery is reduced from that of the M109 howitzer crew in the Division-86 battery.

Similarly, the DSWS is to incorporate state-of-the-art technologies to achieve maximized reliability, availability and maintainability (RAM) through the use of built-in test equipment (BITE), both diagnostic and prognostic. The interest in this example is to examine the impact of reduced maintenance requirements on unit resiliency.

A device to remotely check firing data and supervise firing safety is intended to investigate a means to reduce senior supervision requirements in the DSWS concept of dispersed operations. Such a device is to allow supervisors at a central location to monitor firing data for accuracy and to prevent errors from being fired. The interest in this example is to examine the effect of reduced supervisory requirements on unit resiliency.

Finally, improved wire communications equipment can allow nonspecialists to rapidly emplace relatively short distance (250 meters) internal wire nets. The interest in this example is to examine reduced communication skill requirements on unit resiliency.

3.5 PERSONNEL IMPACTS

The purpose of this step is to examine the impact of specific alternatives to the materiel system design, which were selected in the previous step, on manpower, personnel, and training requirements. The approach is to reflect the impact of system alternatives in changes to the unit METs or transfer matrix, and use AMORE to determine the impact on MPT requirements.

The intent of the device to remotely check and supervise firing data is to reduce the 24-hour senior supervision requirement for the DSWS battery with its widely dispersed positions. Safety and adherence to standard procedures

of operation and security are of prime concern to this level of supervisor (Platoon Leader, Platoon Sergeant and Gunnery Sergeant). Assume that such a device can reduce the requirement (MET) by one NCO per platoon along with his driver and vehicle. The revised METs for this unit are as shown in Table 3-14. The personnel authorizations have not been changed.

The response of the unit with this system design alternative is displayed in Figure 3-17 by the line labeled "REMOTE CHECK". It can be seen that there is a significant increase in unit capability at 12.5% and 25% levels of degradation. Such a device which would make available two senior NCOs to fill in for critical positions as needed is an enhancement to the system design. At 37.5% degradation, the results are basically unchanged from the baseline capability analysis in paragraph 3.2.4.

Although, as discussed earlier, the maintenance personnel requirements should not be considered a consequence of the DSWS system, they do create some reduction in capability for the unit as currently designed. This situation could be improved by aggregating maintenance personnel at battalion level as they are with the Division-86 units. Aggregated at battalion level, their authorized strength versus their requirement and their greater opportunities for substitution should reduce their adverse effect on unit resiliency. However, to examine the unit impact if their requirements (MET) could be reduced, built-in test equipment (BITE) and modular component replacement capability simple enough for the system crew to use is examined. At the same time, the improved wire communication equipment is evaluated. The intent of this alternative is to field equipment which will not require a specially trained communication skill (36K) to install or maintain. As a consequence, not only is the tactical wire specialist removed from the MET, but authorization for both positions is eliminated from the unit. This new MET structure is displayed in Table 3-15.

The response of the unit with these system design alternatives is also displayed in Figure 3-7 by the line labeled "BITE + COMMO". The capability response is particularly good at all levels of degradation because the occasional chokes caused by maintenance and communication skill requirements are eliminated. The most limiting skill group remaining is fire direction (13E).

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Table 3-14. DSWS METs, Remote Check

		MET STRUCTURE							
		TM1	TM2	TM3	TM4	TM5	TM6	TM7	TM8
01	BC	-	-	-	-	1	-	-	-
02	1 SGT	-	-	-	-	1	-	-	-
03	DR/RTO	-	-	-	-	1	-	-	-
04	XO	1	-	-	-	-	-	-	-
05	OPS NCO	1	-	-	-	-	-	-	-
06	SR RD SP	-	-	-	-	-	-	-	-
07	FD SP	2	-	-	-	-	-	-	-
08	NBC NCO	-	-	-	-	-	-	-	-
09	SPT PLSGT	-	-	-	-	-	-	1	-
10	DVR	-	-	-	-	-	-	1	-
11	FS SGT	-	-	-	-	-	-	-	-
12	COOK	-	-	-	-	-	-	-	-
13	SPL SGT	-	-	-	-	-	-	-	-
14	ARM	-	-	-	-	-	-	-	-
15	WIR SP	-	-	-	-	1	-	-	-
16	MT SGT	-	-	-	1	-	-	-	-
17	SP MECH	1	-	-	-	-	-	-	-
18	FA MECH	1	-	-	-	-	-	-	-
19	PLL/EQ	-	-	-	1	-	-	-	-
20	WV MECH	-	-	-	1	-	-	-	-
21	PLTLDR	-	1	-	-	-	1	-	-
22	PLTSGT	-	-	-	1	-	-	-	1
23	DR/RTO	-	1	-	-	-	1	-	-
24	GUN CH	1	1	1	1	1	1	1	1
25	ARV CH	1	1	1	1	1	1	1	1
26	GUNR	1	1	1	1	1	1	1	1
27	CREW	4	4	4	4	4	4	4	4
	TOTAL	13	9	7	11	11	9	9	8
	CUMULATIVE	13	22	29	40	51	60	69	77
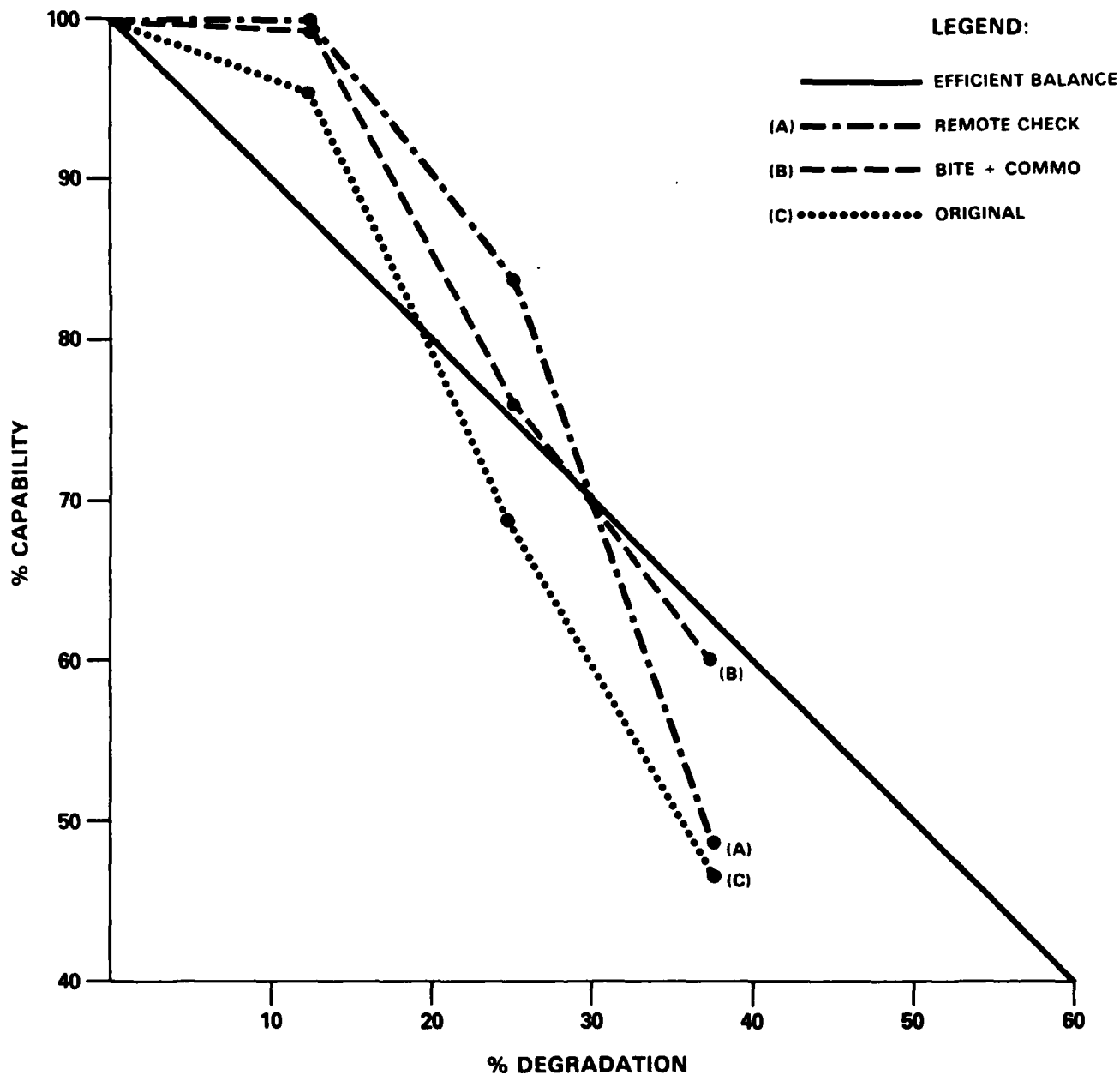
FIGURE 3-7. CAPABILITY VS. DEGRADATION, HARDWARE CHANGES

Table 3-15. DSWS METs, BITE and Commo

		MET STRUCTURE							
		TM1	TM2	TM3	TM4	TM5	TM6	TM7	TM8
01	BC	-	-	-	-	1	-	-	-
02	1 SGT	-	-	-	-	1	-	-	-
03	DR/RTO	-	-	-	-	1	-	-	-
04	XO	1	-	-	-	-	-	-	-
05	OPS NCO	1	-	-	-	-	-	-	-
06	SR RD SP	-	-	-	-	-	-	-	-
07	FD SP	2	-	-	-	-	-	-	-
08	NBC NCO	-	-	-	-	-	-	-	-
09	SPT PLSGT	-	-	-	-	-	-	1	-
10	DVR	-	-	-	-	-	-	1	-
11	FS SGT	-	-	-	-	-	-	-	-
12	COOK	-	-	-	-	-	-	-	-
13	SPL SGT	-	-	-	-	-	-	-	-
14	ARM	-	-	-	-	-	-	-	-
15	- - -	-	-	-	-	-	-	-	-
16	MT SGT	-	-	-	1	-	-	-	-
17	SP MECH	-	-	-	1	-	-	-	-
18	FA MECH	-	-	-	-	-	-	-	-
19	PLL/EQ	-	-	-	1	-	-	-	-
20	WV MECH	-	-	-	-	-	-	-	-
21	PLTLDR	-	1	-	-	-	1	-	-
22	PLTSGT	-	-	-	1	-	-	-	1
23	DR/RTO	-	1	-	-	-	1	-	-
24	GUN CH	1	1	1	1	1	1	1	1
25	ARV CH	1	1	1	1	1	1	1	1
26	GUNR	1	1	1	1	1	1	1	1
27	CREW	4	4	4	4	4	4	4	4
	TOTAL	11	10	7	12	10	10	9	9
	CUMULATIVE	11	21	28	40	50	60	69	78

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Finally, the incorporation of an automatic loader, or similar device to reduce crew authorizations, will have minimal impact on the unit's resiliency. The simultaneous reductions in authorizations and MET requirements leaves the unit response to degradation basically unchanged. However, there is an additional factor which should be carefully considered. This is the requirement for unit manpower to accomplish support tasks. Support tasks are the crew or organizational tasks which are not part of the fighting tasks. They are necessary to the continued performance of the fighting tasks. These tasks can be subcategorized as those which (1) replenish resources expended by the system and crew, or (2) reduce the risk that the system's resources will be unnecessarily expended.

Examples of these support tasks for howitzer crews are:

- Restocking ammunition
- Non-scheduled maintenance
- Sleep
- Perimeter defense
- Camouflage.

A certain amount of these support tasks must be performed every day. Units cannot function without ammunition, sleep, or equipment that functions properly.

Some support tasks require a relatively fixed level of man-hours per day from the unit, regardless of the size of the unit. For example, the number of man-hours required for guarding the perimeter of the unit is not a function of the number of available personnel in the unit although the size of the perimeter which must be guarded could be affected somewhat. Thus, the number of hours required to perform these types of tasks will not decrease in proportion to the number of personnel by which the unit strength or its Mission Essential Team (MET) composition is decreased. Consequently, if the size of the MET and initial strength are reduced, the average number of hours required per crew member to perform these tasks will increase. When considering the size to

which the MET and initial strength can be reduced as a result of the intro-
duction of a labor-saving design feature, consideration should be given to
whether the reduced size MET will be able to execute their missions, perform
their functions, and also accomplish their replenishment and risk reduction
tasks. Some reductions in the size of the METs and the authorized strength of
the unit may result in insufficient personnel and man hours per day available
to accomplish all necessary combat and support tasks.

The following is an example of support task requirements for the M109-
series howitzer crew. For a ten and a seven man crew size, each fire unit has
a requirement for the replenishment and risk reduction task performance hours
shown in Table B-3. The average number of hours per day per person required
for these types of tasks is 15.1 for a ten man crew and 17.3 for a seven man
crew. This difference is large and could cause serious problems with a unit's
ability to operate for extended periods. There are 73 man-hours per day of
crew support tasks which are independent of crew size. These tasks are iden-
tified in Table B-3 by the same man-hours/day requirement in both crew-size
columns (e.g., the tasks of replenish ammo and POL). Additionally, 6 man-
hours per day per man in the crew are required for other support tasks (sleep,
dig foxhole, and personal maintenance). This example demonstrates that when
reductions in crew size are being contemplated, increases in the per person
replenishment and risk reduction task requirements should be considered and
their effects weighed. Thus, crew savings below a fixed level may be unaccep-
table unless alternatives in doctrine or support can be developed which reduce
the required support tasks.

Before developing some issues involving changes to a unit's transfer
matrix, an index of a unit's substitutability is useful as a comparative mea-
sure. Although many different measures could be developed, the following two
will be used in this report.

Table 3-16. Howitzer Battery Support Tasks

Replenishment Tasks	Man-Hours/Day[1]	
	10 man crew	7 man crew
Replenish Ammunition	16	16
Replenish POL	1	1
Non-Scheduled Maintenance	4	4
Sleep (@4 hours)	40	28
Supply Duties	6	6
*Personal Maintenance (@1 hour)	10	7
Identify and Prepare New Firing Positions	12	12
(sub-total)	89	74

Risk Reduction Tasks		
Preventative Maintenance	1	1
$Perimeter Defense	20	20
Guard Nuclear Ammo	5	5
*Improve Positions	2	2
*Camouflage	2	2
*Foxholes (@1 hour per)	8	5
*Crew Served Weapon Position (1 ea)	4	4
(sub-total)	42	39

Involuntary Downtime While Moving	20	8
	—	—
(Grand Total)	151	121
	÷10	÷7
	15.1	17.3

[1]All task times except those identified with a * were taken from Crumley, L.M., Schwalm, R.C., and Coke, J.S., 1982.

$Assumes two guards at each of four stations with the battery operating as an eight gun unit.

*Estimates taken from Contribution of Infantry to the Battlefield, 1978.

Let A be a unit of measure defined as

$$A = \frac{S_{ij} \times S_j}{N(N-1)} \quad , i \neq j; \; i = 1, \ldots, K; j = 1, \ldots, K$$

where S_{ij} is the number of personnel in skill i who can substitute for skill j, S_j is the number of personnel in skill j, N is the total number of personnel in the unit, and K is the number of skill groups in the Transfer Matrix.

Let B be a unit of measure defined as

$$B = \frac{T_i}{K(K-1)} \quad , i = 1, \ldots, K$$

where Ti is the number of skills into which skill i can transfer, and K is the total number of skill groups in the Transfer Matrix. The value of Ti can be determined directly from the "TRANS" column in the Transfer Matrix.

One other feature of this unit which deserves investigation is the impact of different training situations on the capability response. The training situation is primarily reflected in the personnel transfer matrix of a unit. Table 3-11 is the original transfer matrix for the DSWS battery. Its two substitutability indices are: A = 0.386 and B = 0.209.

Table 3-16 is the transfer matrix for a well trained (cross-trained) DSWS battery. Several additional feasible substitutions are allowed in this situation beyond those indicated in Table 3-11. Its two substitutability indices are: A = 0.428 and B = 0.248 which indicate increased substitutability of 11% and 19% respectively.

Table 3-17 is the transfer matrix for a poorly cross-trained unit. Primary emphasis is on restricting junior personnel from substituting into higher skill levels or to more difficult skills. For this situation, A = 0.298 and B = 0.160 which indicate decreased substitutability from the original situation of 23% and 24% respectively.

Figure 3-8 illustrates the impact of these training differences on the DSWS battery. The better trained unit has a much better response to degradation than the original unit. The poorly trained unit responds well below the original unit. Neither of these training conditions is unusually extreme. They could each be representative of real unit situations.

3.6 DEGRADED ENVIRONMENT ANALYSIS

The purpose of this step is to extend the analysis of the previous step to examine the impact of system design alternatives on personnel in a degraded environment such as that produced by fatigue, reduced teamwork, or a chemical warfare environment. The approach is to develop degraded environment situations which will produce critical skills, relate the critical skills to system alternatives, and quantify the effect on unit resiliency.

Of particular interest in an examination of degraded environments is the emergence of critical personnel skills and new insights into personnel interactions with features of the new materiel, system design. In other words, it is not the reaction of the unit to these degraded environments that is of interest so much as the identification of previously undetected personnel skill problems with the unit which could be alleviated by changes to the materiel system design.

Fatigue is typical of the type of individual degradation which does not remove personnel from the available strength of a unit, but does reduce their effectiveness within the unit. A major effect of fatigue on personnel is to

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Table 3-17. DSWS Enhanced Personnel Transfer Matrix

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	TRANS
01	BC	13E0	0	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	30	–	–	–	–	–	–	2
02	1SGT	13Y5	15	0	90	90	–	–	–	–	0	0	–	–	–	–	–	–	–	–	–	–	90	30	30	30	–	–	–	9
03	DR/RTO	13B1	–	–	0	–	–	–	90	–	–	–	–	–	–	–	90	–	–	–	–	–	–	–	30	–	90	60	30	7
04	XO	13E0	0	–	0	0	0	90	–	–	–	–	–	–	–	–	–	–	–	–	–	–	30	–	–	–	–	–	–	4
05	OPSNCO	13E3	–	30	30	0	30	0	0	–	90	30	–	–	–	–	30	–	–	–	–	–	–	–	30	–	45	–	30	5
06	SRFDSP	13E2	–	–	–	90	30	0	0	–	–	30	–	–	–	–	30	–	–	–	–	–	–	–	30	–	90	–	30	9
07	FDSP	13E1	–	–	30	–	60	15	0	–	–	0	–	–	–	–	15	–	–	–	–	–	45	–	30	–	45	30	30	8
08	NBCNCO	54E2	–	–	0	–	–	–	90	0	0	0	–	–	–	–	–	–	–	–	–	–	–	30	–	–	–	60	–	8
09	SPLTSG	13B4	90	0	0	–	–	–	–	–	0	90	0	0	–	–	–	90	–	–	–	–	45	30	30	30	90	–	30	8
10	DR	13B1	–	–	0	0	–	–	90	0	–	0	0	0	–	–	60	–	–	–	–	–	–	–	30	–	90	–	30	6
11	FSSGT	94B4	–	60	60	–	–	–	–	–	30	60	0	0	30	–	90	–	–	15	–	–	–	–	90	–	90	90	90	5
12	COOK	94B–	–	–	–	–	–	–	–	–	–	60	30	0	0	0	0	–	–	30	60	–	–	–	–	–	–	60	60	6
13	SPLSGT	76Y3	–	30	0	–	–	–	90	–	30	0	–	–	0	–	15	75	90	0	15	–	–	–	–	–	90	–	60	7
14	ARM	76Y2	–	–	0	–	–	–	–	–	90	0	–	–	30	0	0	–	100	100	0	100	–	–	30	–	90	–	90	10
15	WIRSP	36K1	–	–	0	–	–	–	–	0	–	0	–	–	–	–	0	–	0	90	90	0	–	–	–	–	–	–	–	5
16	MTSGT	63D4	–	60	–	–	–	–	–	–	45	–	–	–	–	–	–	–	0	0	15	0	–	–	30	–	–	–	–	6
17	SPMECH	63D–	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	60	0	90	15	60	0	0	–	90	–	–	90	5
18	FAMECH	45D–	90	–	–	–	–	–	–	–	–	–	–	–	–	–	–	75	90	0	15	60	0	0	90	0	–	–	90	5
19	PLL/EQ	76C–	–	–	15	–	–	–	–	–	–	15	–	–	–	–	–	–	100	100	0	100	–	–	–	–	–	–	90	7
20	WVMECH	63B1	–	–	0	–	–	–	–	–	–	–	–	–	–	–	–	90	90	90	15	0	–	–	90	–	–	–	90	5
21	PLTLDR	13E0	60	–	–	30	30	–	–	–	30	–	–	–	–	–	30	–	–	–	–	–	0	0	–	90	–	–	–	5
22	PLTSGT	13B4	90	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	0	90	0	–	0	–	7
23	DR/RTO	13B1	–	–	30	–	–	–	–	–	–	30	–	–	–	–	–	–	–	–	–	–	–	–	0	–	45	60	0	6
24	GUNCH	13B3	–	90	–	–	–	–	–	–	45	–	–	–	–	–	–	–	–	–	–	–	60	–	–	0	0	0	0	7
25	ARVCH	13B2	–	–	30	–	–	–	–	–	90	30	–	–	–	–	–	–	–	–	–	–	–	30	0	0	0	0	0	8
26	GUNR	13B2	–	–	90	–	–	–	–	–	–	90	–	–	–	–	30	–	–	–	–	–	–	30	90	0	30	0	0	7
27	CREW	13B1	–	–	45	–	–	–	–	–	–	45	–	–	–	–	–	–	–	–	–	–	–	–	15	90	30	45	0	7
	SUBSTITUTES		5	7	13	5	5	3	5	0	9	13	1	1	2	1	10	5	4	4	8	4	6	6	13	7	12	8	17	174

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Table 3-18. DSWS Restricted Personnel Transfer Matrix

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	TRANS
01	BC	13E0	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
02	1SGT	13Y5	15	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	30	-	30	-	-	-	5
03	DR/RTO	13B1	0	-	0	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	30	3
04	XO	13E0	0	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	3
05	OPSNCO	13E3	-	30	30	30	0	0	0	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	4
06	SRFDSP	13E2	-	-	30	90	30	0	0	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	30	-	45	-	30	9
07	FDSP	13E1	-	-	30	-	-	-	0	0	-	30	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	30	4
08	NBCNCO	54E2	-	-	0	-	-	-	0	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	30	30	-	30	30	4
09	SPLTSG	13B4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45	30	30	30	-	-	-	5
10	DR	13B1	-	-	0	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	30	3
11	FSSGT	94B4	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
12	COOK	94B-	-	60	60	-	-	-	-	-	30	60	0	0	0	0	0	0	0	-	15	-	-	-	90	-	-	-	90	4
13	SPLSGT	76Y3	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	60	60	-	15	0	-	-	30	-	90	-	60	5
14	ARM	76Y2	-	-	0	-	-	-	-	-	-	0	-	-	-	-	-	-	-	0	15	0	-	-	-	-	-	-	60	4
15	WIRSP	36K1	-	-	0	-	-	-	-	-	-	0	-	-	-	-	0	-	-	-	0	0	-	-	30	-	-	-	90	4
16	MTSGT	63D4	-	60	-	-	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	6
17	SPMECH	63D-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	60	0	-	15	0	-	-	-	-	-	-	90	4
18	FAMECH	45D-	-	-	15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	15	-	-	-	-	-	-	-	-	2
19	PLL/EQ	76C-	-	-	-	-	-	-	-	-	-	15	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	90	3
20	WVMECH	63B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	90	-	15	0	-	-	-	-	-	-	90	3
21	PLTLDR	13E0	60	-	-	30	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-	-	4
22	PLTSGT	13B4	-	60	-	-	30	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	0	0	0	0	-	0	0	5
23	DR/RTO	13B1	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	0	3
24	GUNCH	13B3	-	90	-	-	-	-	-	-	45	30	-	-	-	-	-	-	-	-	-	-	-	0	-	0	0	0	0	6
25	ARVCH	13B2	-	-	30	-	-	-	-	-	90	30	-	-	-	-	-	-	-	-	-	-	-	30	0	0	0	0	0	8
26	GUNR	13B2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	0	0	0	0	4
27	CREW	13B1	-	-	45	-	-	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	15	0	-	1	0	3
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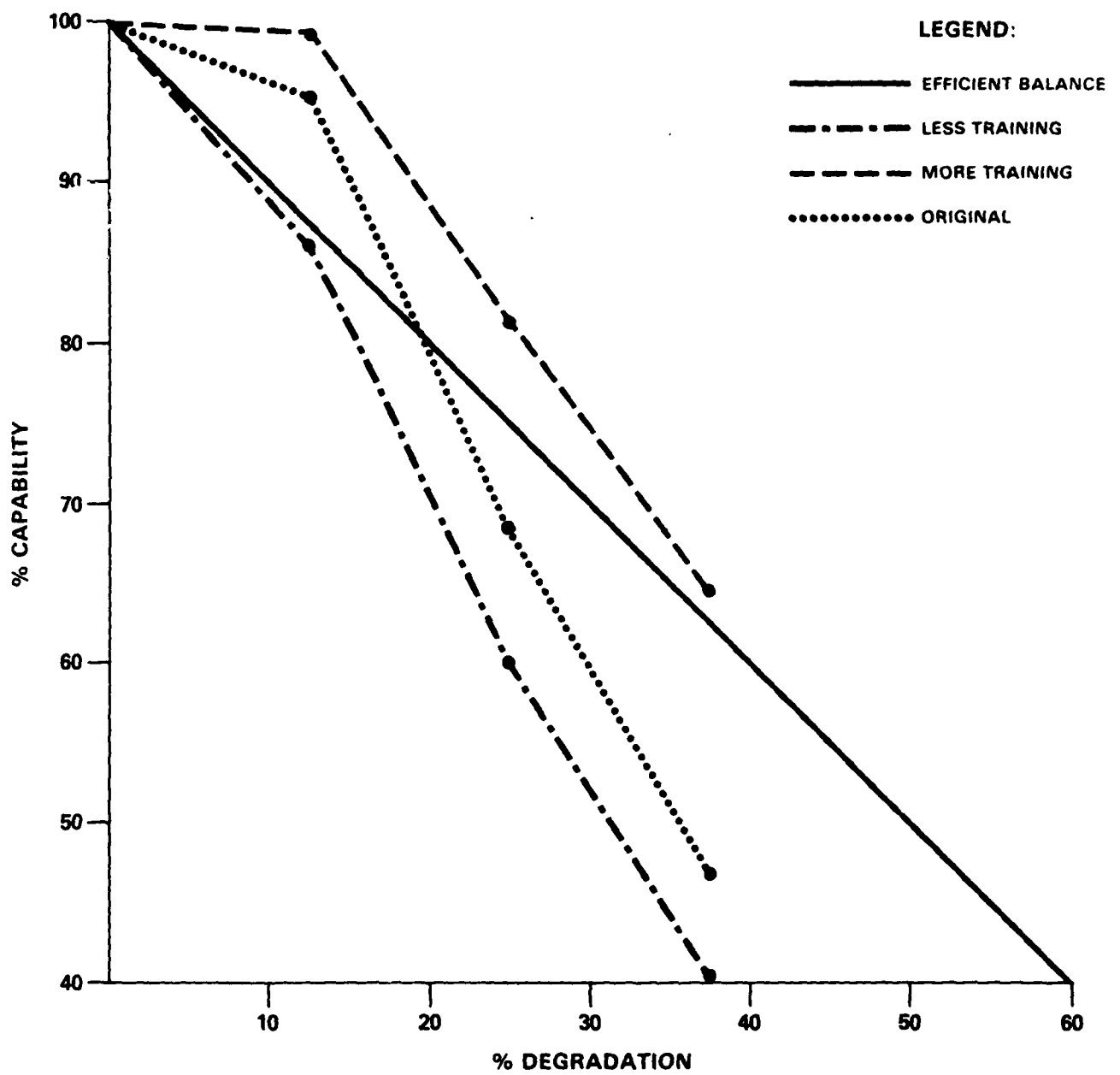
FIGURE 3-8. CAPABILITY VS. DEGRADATION, TRAINING CHANGES

reduce their cognitive ability, and so a possible approach to analyzing the impact of fatigue on a unit is to restrict substitutions into higher cognitive skills.

Table 3-18 is an example of how the DSWS firing battery personnel might be rank ordered by the cognitive requirements of the listed duty positions. The positions with the greatest cognitive requirements are at the top of the list. The brackets include duty positions with essentially equivalent cognitive requirements. This rank ordering is then translated into an effect on substitutability by eliminating from the original transfer matrix in Table 3-11 any substitutions from one position to another which are higher on the rank ordered list. The revised transfer matrix is shown in Table 3-19. The substitutability indices for this matrix are: A = 0.257 and B = 0.141. Recall that the indices for the normal situation were A = 0.386 and B = 0.209. Thus, this measure of fatigue degradation indicates a 33% loss of substitutability according to both indices.

The response of the unit to that reduced substitutability is shown in Figure 3-9. The reduction in capability is greater than 30% at all levels of degradation. Not too surprisingly, the skills at the top of the rank ordered list caused the most problem. The Battery Commander, Maintenance Sergeant and the Platoon Leaders respectively were responsible for the three largest needs. In fact, the top five skills in Table 3-18 accounted for 69% of all needs at the 37.5% level of degradation and 75% of all needs at the 25% level.

While the translation of the effects of fatigue into substitutability, such as was used in this example, is probably too severe and, at a minimum, could be offset a great deal by proper unit training, it does illustrate the process which can be employed. It also has pointed out the potential criticality of highly cognitive skill requirements and the benefit in lowering those requirements.

A chemical warfare environment requires individual or collective protection or both. In most cases, the protective measures consist of special pro-

Table 3-19. DSWS Cognitive Skill Rating

	Line #	Title	MOS
01	01	BTRY CDR	13E00
02	04	XO	13E00
03	21	PLT LDR	13E00
04	05	OPS NCO	13E30
05	16	MAINT SGT	63D40
06	06	SR FD SP	13E20
07	17	SP FA AUTO MECH	63D--
08	18	FA WPNS MECH	54D--
09	20	PWR GEN/WV MECH	63B10
10	07	FD SP	13E10
11	08	NBC NCO	54E20
12	19	PLL/EQ MAINT CLK	76C--
13	02	FIRST SGT	13Y5M
14	22	PLT SGT	13B40
15	09	SPT PLT SGT	13B40
16	24	GUN CHIEF	13B30
17	26	GUNNER	13B20
18	13	SUPPLY SGT	76Y30
19	14	ARMORER	76Y20
20	11	FOOD SVC SGT	94B40
21	25	ARV CHIEF	13B20
22	03	DRIVER	13B10
23	23	DRIVER	13B10
24	10	DRIVER	13B10
25	12	COOK	94B--
26	15	TAC WIRE SP	36K10
27	27	GUN CREW	13B10

Table 3-20. DSWS Fatigue Degraded Transfer Matrix

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	TRANS
01	BC	13E0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	2
02	1SGT	13Y5	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	30	-	-	-	3
03	DR/RTO	13B1	-	-	0	-	-	-	-	-	-	0	-	-	-	-	90	-	-	-	-	-	-	-	30	-	-	-	30	4
04	XO	13E0	0	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	30	-	-	-	3
05	OPSNCO	13E3	-	30	-	-	0	0	0	-	-	30	-	-	-	-	30	-	-	-	-	-	-	-	30	-	45	-	30	3
06	SRFDSP	13E2	-	-	30	-	-	0	0	-	0	30	-	-	-	-	30	-	-	-	-	-	-	-	30	-	90	-	30	7
07	FDSP	13E1	-	-	30	-	-	-	0	-	-	30	-	-	-	-	30	-	-	-	-	-	-	-	30	-	45	-	30	6
08	NBCNCO	54E2	-	-	0	-	-	-	-	0	-	0	-	-	-	-	15	-	-	-	-	-	-	30	-	30	-	30	-	6
09	SPLTSG	13B4	-	0	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	4
10	DR	13B1	-	-	0	-	-	-	-	-	-	0	-	0	-	-	60	-	-	-	-	-	-	-	30	-	-	-	-	4
11	FSSGT	94B4	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	2
12	COOK	94B-	-	-	-	-	-	-	-	-	-	-	-	0	0	0	90	0	0	0	0	0	-	-	-	-	-	-	60	2
13	SPLSGT	76Y3	-	-	0	-	-	-	-	-	-	0	-	-	0	0	0	-	0	90	15	15	-	-	30	-	90	-	60	4
14	ARM	76Y2	-	-	0	-	-	-	-	-	-	0	-	-	30	0	15	-	-	0	0	60	-	-	-	-	-	-	90	7
15	WIRSP	36K1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	1
16	MTSGT	63D4	-	60	-	-	-	-	-	-	45	-	-	-	0	0	0	0	0	0	0	0	-	-	-	-	90	-	-	6
17	SPMECH	63D-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	90	15	0	-	-	-	-	90	-	90	4
18	FAMECH	45D-	-	-	-	-	-	-	-	-	-	15	-	-	-	-	15	-	-	0	15	60	-	-	-	-	90	-	90	3
19	PLL/EQ	76C-	-	-	15	-	-	-	-	-	-	15	-	-	-	-	0	-	-	-	0	-	-	-	-	-	90	-	90	3
20	WVMECH	63B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	15	0	-	-	-	-	-	-	90	2
21	PLTLDR	13E0	-	-	-	30	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	3
22	PLTSGT	13B4	-	60	-	-	30	-	-	-	-	30	-	-	-	-	30	-	-	-	-	-	0	0	-	0	-	-	-	4
23	DR/RTO	13B1	-	-	30	-	-	-	-	-	-	30	-	-	-	-	30	-	-	-	-	-	0	0	0	-	-	-	-	4
24	GUNCH	13B3	-	-	-	-	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	-	0	-	-	0	0	-	0	5
25	ARVCH	13B2	-	-	30	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	0	-	0	-	0	4
26	GUNR	13B2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	0	0	3
27	CREW	13B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
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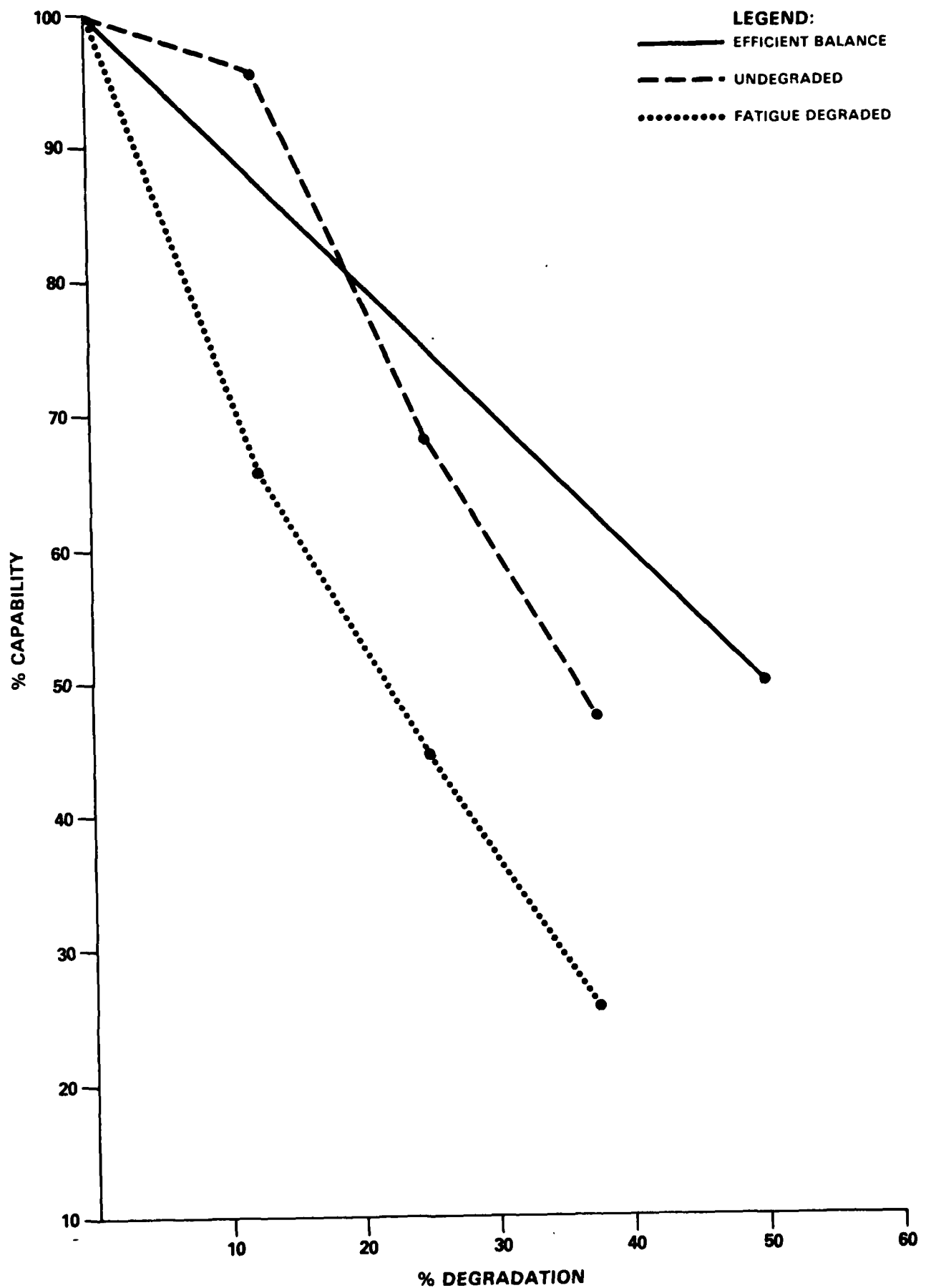
FIGURE 3-9. CAPABILITY VS. DEGRADATION, FATIGUE DEGRADED

tective clothing and a mask for each individual. Even under ideal weather conditions, this individual protective equipment degrades the work performance of each individual because of difficulties with communication, dexterity, and general discomfort. In addition, the effects of heat build up will seriously degrade the work performance of those personnel involved in heavy labor.

Measurements can be made of individual work performance in such an environment resulting in calculations of individual productivity. For the sake of illustration, the following example values for the DSWS Firing Battery will be used to determine the impact on unit resiliency.

Table 3-21. Degraded Productivity, DSWS Firing Battery

Skill	Productivity
01 BC	0.8
02 1SGT	0.8
03 DR/RTO	0.8
04 XO	0.8
05 OPSNCO	0.8
06 SRFDSP	0.8
07 FDSP	0.8
08 NBC NCO	0.9
09 SPLTSG	0.8
10 DR	0.8
11 FSSGT	0.8
12 COOK	0.8
13 SPLSGT	0.8
14 ARM	0.8
15 WIRSP	0.8
16 MTSGT	0.5
17 SPMECH	0.5
18 FAMECH	0.5
19 PLL/EQ	0.8
20 WVMECH	0.5
21 PLTLDR	0.8
22 PLTSGT	0.8
23 DR/RTO	0.8
24 GUNCH	0.8
25 ARV CH	0.8
26 GUNR	0.7
27 CREW	0.5

Using the PERDEG utility program, which is part of the Apple AMORE version of the software, these reduced individual productivity rates are converted into unit capability as a function of time. If the Apple AMORE software is not available, manual calculations can be made using the equations in Section 2.6 [see also paragraph 2.4.4.3 of AMORE, User's Handbook, 1982].

Output of the PERDEG program at the level of 25% degradation indicates that the lower bound on maximum unit capability which can be recovered is 35.6%. This value represents the case where teams are not trained to reallocate work requirements, thus performance is constrained by the slowest team member. The upper bound on unit capability which can be reconstituted is 46.5%, an increase of 31% over the lower bound. This value represents the case where teams are fully trained to reallocate (balance) work requirements to achieve the optimum productivity.

For the DSWS Firing Battery with full individual productivity, the maximum capability which can be reconstituted after 25% degradation is 69.2% (see Section 3.2.4). Thus, this analysis also indicates that the individual degraded productivities shown in Table 3-21 will cause at least an additional 33% loss in maximum capability for the battery after 25% degradation. Individual levels of productivity can be varied and unit capability recalculated to identify specific skills which have the greatest effect on unit resiliency.

The preceeding discussion on analysis of a degraded environment does not describe how to obtain necessary input data. The section does describe how to use proper input data to obtain information and insight about unit resiliency and individual skill contributions to that resiliency in various types of degraded environments. ARI TR 386 [Pfeiffer, M.G., et. al., 1979] describes some of the effects on individual performance of the types of degradation which are of interest in this step. It also contains an extensive reference list for additional source materiel.

3.7 CONCLUSIONS

The preceeding examples are not intended to produce a complete analysis of the manpower, personnel, and training impacts of the DSWS. They are intended to illustrate an AMORE based methodology which can be used to systematically examine the relationships between materiel system design changes, their MPT consequences, and their effect on the ability of the parent unit to form mission essential capability following degradation. However, some conclusions can be made based upon the research results presented herein.

The capability analyses and the DSWS unit design analysis illustrate clearly that maintenance skills are the most consistent skill shortfall in the DSWS battery. Senior leadership or supervisor skills (grade E-7 and above) and fire direction skills (13E) are also critical skills. The analysis also shows the questionable value of reducing fire direction (13E) skills in the DSWS unit, since these are typically more flexible and cross-trainable personnel.

Two different substitutability indices are discussed and compared throughout various examples. Although neither index is totally predictive of the impact of change on unit capability response, both are helpful in understanding the type of change to substitutability which is being examined, i.e., primarily personnel oriented or primarily skill oriented.

Substitutability can have a great effect on the resulting unit capability response to degradation, and thus is very critical as a data input. Sensitivity analysis in this area may be appropriate for many situations. A unit which is population limited has adequate substitutability. Increased training is the primary means to improve substitutability.

Although the reduction in crew authorizations for the DSWS firing battery from the Division-86 howitzer battery has no adverse effect on unit capability response, and some additional reductions may even be possible, the requirements generated by unit support tasks need to be considered carefully. The additional unit task requirements establish a lower limit on crew size.

Several possible DSWS hardware alternatives are analyzed for their manpower, personnel, and training impacts. Changes which lower supervisor requirements result in improved unit capability response. Reducing unit maintenance and communication skill requirements have a very positive impact on unit resiliency. The reduction of crew size has a minimal impact on unit resiliency.

Degrading factors, such as fatigue or a chemical warfare environment, can have a great effect on unit resiliency. While the inputs which characterize individual performance in degraded environments may be difficult to develop, the AMORE methodology can easily transform those inputs into their effect on unit resiliency.

Finally, the approach presented in this report to applying the AMORE methodology to manpower, personnel, and training front-end analysis of new materiel systems can be used early in the development cycle based upon comparability analysis and support from a HARDMAN analysis for input data. It is equally useful at any later stage when improved system and unit design information is available.

APPENDIX A
REFERENCES

APPENDIX A
REFERENCES

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APPENDIX B
RESEARCH REPORT

APPENDIX B

RESEARCH REPORT

The purpose of this Appendix is to report on the research which was con-
ducted in support of Task 3. The research objective was to develop an under-
standing of ways in which the AMORE methodology could help to accommodate
human factors issues at an early point in the development of new Army materiel
systems. The research was to examine ways to deal with the uncertainties of
AMORE constructs of unit personnel at an early stage of system development and
to establish linkages between hardware system alternatives and MPT require-
ments.

The research path led to an examination of the HARDMAN methodology and
consideration of the advisability of integrating AMORE with HARDMAN in order
to achieve the objectives of Task 3. AMORE research concentrated on the ef-
fect which changes in major areas of AMORE input data have on unit design and
an organization's resiliency. In particular, the effect of changes of unit
authorized strength, MET requirements, and substitutability were examined.
Although the time and resources available to complete that research as part of
this contract were not sufficient for a complete investigation, it did provide
useful information and insights which contributed to the methodology reported
in Section 2. The topics which follow are organized in the sequence in which
they were investigated to help convey their relationship to each other as
developed by the researchers.

B.1 ETES

The Statement of Work included guidance that the research would consider
the degree to which the Early Training Estimation System (ETES), and espe-
cially its System Description Technology (SDT) component, could provide input
to the AMORE-based methodology being developed for Task 3.

ETES was an ARI sponsored project to provide the capability for system-
atically estimating training requirements during the earliest phases of the

weapon system acquisition process [Early Training Estimation System: Yearly Report, 1982]. ETES was specifically intended to overcome three major deficiencies in the current capability for developing early estimates of training requirements:

- Lack of a systematic flow of information among participants in the acquisition process.

- Lack of estimation procedures/aids appropriate to the design process.

- Lack of systematic technology for rapidly evaluating training alternatives.

ETES was designed with four major components: a System Description Technology (SDT), Training Estimation Aids and Procedures, an Evaluative Technology, and a User's Guide. The SDT was to be an automated data base management system for describing actual and projected system elements, including functional requirements, design concepts, tasks, skills, training program elements, and their associated resources; for storing that information; for changing and updating that information; and for transmitting the information among all of the participants in the acquisition process.

An examination of ETES/SDT indicated that it would contain many useful elements of data for an AMORE-based analysis. The SDT data base would be very helpful in developing the AMORE inputs by making available system functional requirements, design concepts, tasks, and skills. During the Task 3 research, ETES/SDT was still in early development and so no specific examples of system data were available for investigation. The examination of ETES, however, did lead to a more detailed investigation of the HARDMAN methodology since ETES was apparently tailored to contain a data base which would support that methodology. It was initially anticipated that an investigation of HARDMAN would provide a better understanding of the eventual capabilities and utility of ETES, but it was to develop into an attractive research path of its own.

B.2 HARDMAN METHODOLOGY

For the past few years, ARI has sponsored research into the utility of the HARDMAN methodology for developing the manpower, personnel, and training

requirements of emerging Army weapon systems [e.g., Application of the HARDMAN Methodology to the Division Support Weapon System, 1982].

The Military Manpower/Hardware Procurement or HARDMAN methodology is an integrated set of data base management techniques and analytic tools designed to assess the human resource requirements and costs associated with an emerging system's design. It is also capable of determining the impact of those human resource requirements on the total Army. The basic analytic approach used by the methodology is comparability analysis in which data from similar existing systems and subsystems are modified and aggregated to form a description of the human resource demands of the proposed system.

The basic HARDMAN methodology is a six-step process starting with consistent data definition across the various models employed. It has recently been expanded to 12 steps which are more discretely developed than in previous work. The process begins with a determination of the new system's functional requirements. These are compared to the functional requirements of existing technology or system components and, on the basis of these analyses, comparable technology is identified. This technology is used to define the initial design of the new system and is modified to reflect the latest advances in technology. Tasks, skills, and manpower required to operate the system are determined from the mature data associated with the existing technology. Allowances are made for the effect of newer technology. Training resources and personnel requirements are derived together with the costs and impacts of these requirements. Finally, a trade-off analysis is conducted. In 12 steps, the process is:

1. Functional Requirements Analysis - determines the range and depth of all the functions that the system is required to perform on the battlefield.

2. Engineering Analysis - interprets the system in technical design terms to analyze and define proposed design alternatives and assess their impact on human resources.

3. Reliability/Maintainability Analysis - collects mature R/M data for each functional group code within the reference system.

4. Task Identification - specifies what tasks operators and maintainers of the reference and proposed systems will perform.

5. MOS/Grade Assignment - determines the personnel positions required to operate and maintain the proposed system.

6. Mission Analysis - associates workload estimates with a specified set of system missions on the battlefield.

7. Workload Analysis - determines the distribution of the total workload generated by the proposed system in accomplishing assigned battlefield functions.

8. Manpower Requirements Determination - converts operator and maintainer workloads to actual numbers of each MOS required.

9. Training Resource Requirements Analysis - estimates the resources and costs associated with the training of the operators and maintainers.

10. Personnel Requirements Analysis - estimates the number of personnel needed to sustain any one set of system specific manpower requirements.

11. Impact Analysis - determines the demand of the proposed system upon the present and future supply of personnel and training resources.

12. Tradeoff Analysis - iterates the methodology to develop the most effective response to each critical resource requirement.

B.3 HARDMAN-AMORE INTEGRATION

The HARDMAN process develops manpower data, in terms of actual numbers of each MOS which are required per emerging system, which is directly usable in AMORE-based analysis. Using the data which is developed through the first eight steps above, the Mission Essential Teams (METs) of the AMORE methodology can be developed, skill substitutability identified, and special organizational requirements recognized. At this point, AMORE could be used to determine the adequacy of these manpower requirements (too many, too few, critical skills, etc.) based upon their impact on crew and unit resiliency.

This research effort examined two approaches to a HARDMAN-AMORE integration. The Division Support Weapon System (DSWS) was selected as a candidate emerging system because of the availability of some HARDMAN analysis data and because of the existence of ARI crew task analysis and AMORE analysis of the DSWS predecessor (reference) system - the M109 howitzer.

The first approach considered was to conduct an AMORE analysis, based upon the data developed during the first eight steps of the HARDMAN analysis, to identify any critical skills in the unit along with potential solutions based upon improved skill availability or new training. Then reverse the HARDMAN analysis process tracing those critical skills back into their hardware sub-system roots identified in the Engineering Analysis of Step 2 in HARDMAN. The objective was to identify the key cause and effect relationships so that the impact of emerging system design changes could be directly quantified. Although this approach was straightforward and appeared feasible, there were questions about its practicality. In fact, far too little actual data from the HARDMAN analysis of the DSWS (or any other Army system) was available to allow trial calculations to be made. The process threatened to be particularly slow and manpower intensive. Finally, it was feared that the derived relationships would not be as clear as anticipated and that the same results could be achieved with a less difficult approach.

The second approach was to take greater advantage of the potential offered by ETES. To a large extent, ETES was to be a partial automation of the HARDMAN methodology to include automated management of the data base. That fact offered a more efficient procedure to accomplish essentially the same goal as the first approach. The critical skills which were identified in the AMORE analysis could be "fixed" in a variety of ways by modifications at earlier points in the HARDMAN analysis (e.g., MOS and grade assignment, workload distribution, or the system design itself). If the HARDMAN analysis could be perturbated in a reasonably fast and efficient manner, then a variety of changes could be examined in search of a "better" solution. No consideration was given to an algorithm for obtaining an optimal solution. The major relationships and sensitivity which would be quantified in such an approach should be fully sufficient to identify those "better" solutions. This approach can be summarized as conducting an AMORE analysis of the new unit, based upon HARDMAN analysis for input, in order to identify possible improvements to the system design. Then make changes to the system design and repeat HARDMAN until a "best" solution is reached. In this case, a best solution is the one producing a resilient unit with less MPT requirements than other solutions examined.

Although this latter approach offered potential to get the best from both the HARDMAN and AMORE methodologies which was attractive in terms of time and resources required, and although much additional work was needed to clarify and develop the above concept in detail, further effort in this direction was terminated at this point. That decision was due primarily to the decision to discontinue further development of ETES/SDT. The value of linking the HARDMAN and AMORE methodologies remains and, in fact, the process presented in Section 2 of this report is a beginning in that direction. Additional investigation is needed to better understand the interaction of the two methodologies, the interpretation of their results, and the most efficient set of combined steps.

B.4 AMORE RESEARCH

This section is a report on some of the basic research into the AMORE methodology which was conducted in support of Task 3. The vast majority of the research was completed using the Division-86 Howitzer Battery as a test case. The research was conducted predominantly before the methodology described in this report was developed, and the concept at that time was to examine the "current organization" to understand its reaction to the potential changes as a predictor of the reaction of the new organization to similar changes. In fact, in the very early conceptual stage of a materiel system development, that approach still has merit for evaluating potential changes. It can even be helpful in developing an Operational and Organizational concept for the new system.

The first factors to be examined are the unit authorized strength and the Mission Essential Team (MET). When only the authorized strength is decreased, the unit's capability response to degradation decreases as expected. Figure B-1 contains graphs of capability versus degradation for the Division-86 battery when its authorized strength is reduced by eight personnel in MOS 13B10 (line "B") and also when reduced by 16 personnel in MOS 13B10 (line "C"). Since the personnel requirements as stated by the METs remain unchanged, the unit capability becomes very limited by a shortage of personnel. Shown in Table B-1 below are the expected unit survivors at each level of degradation

LEGEND:
——— EFFICIENT BALANCE
(A) — — — FULL AUTH; FULL MET
(B) •••••• REDUCED (–8): FULL MET
(C) •–•–•– REDUCED (–16): FULL MET
(D) •••••••• FULL AUTH; REDUCED (–8)
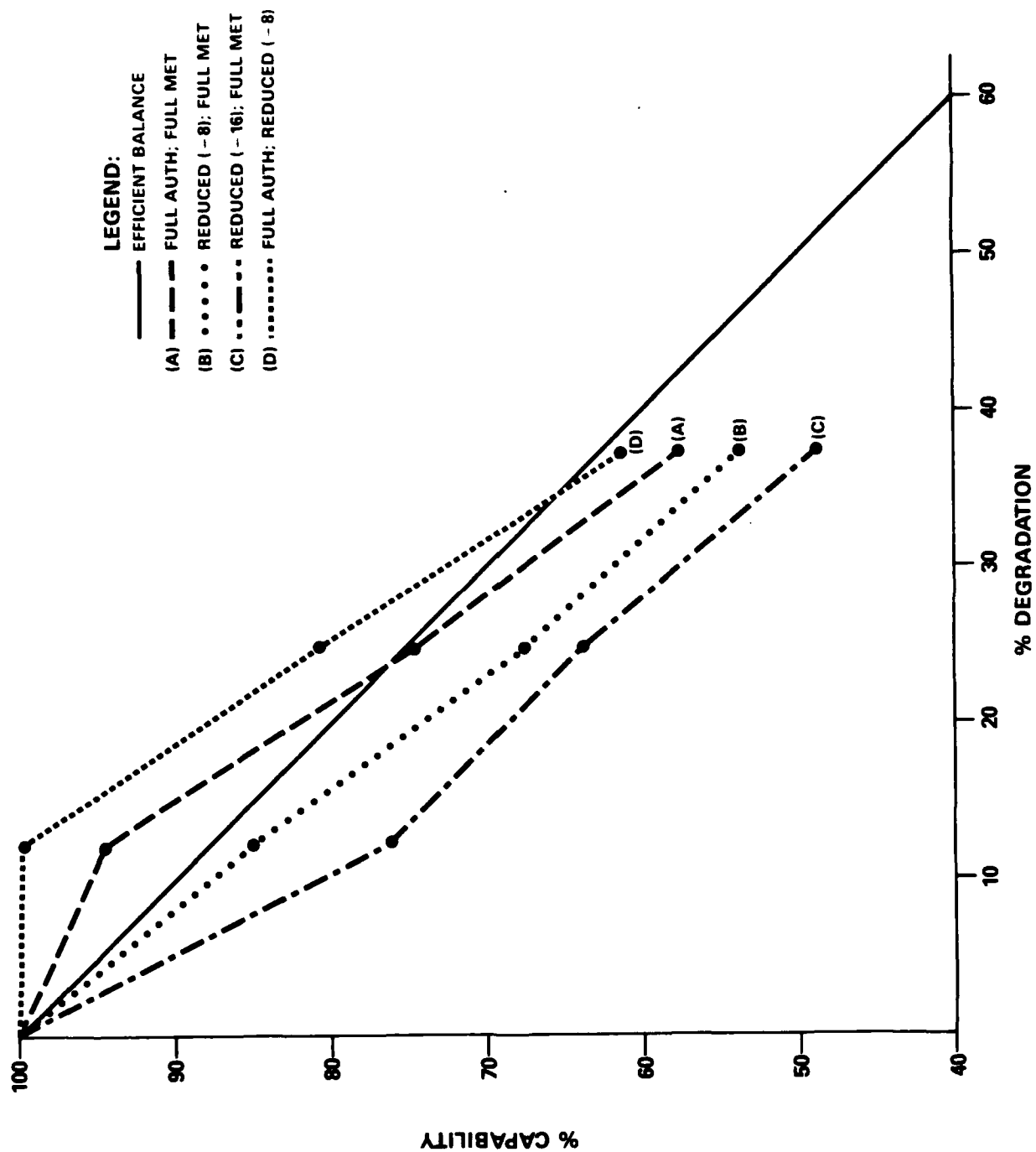
FIGURE B-1. CAPABILITY VS. DEGRADATION, VARYING AUTH. OR MET

together with the MET requirements for Team 7 (12.5% level), Team 6 (25%), and Team 5 (37.5%). The title "Survivors (A)" refers to the full unit authorization, "Survivors (B)" represents the unit reduced by eight authorizations, and "Survivors (C)" represents the unit reduced by 16 authorizations. The data below clearly illustrates that the reduced units (B) and (C) do not expect to have enough personnel on the average to meet the corresponding MET requirements. For example, Survivors (C) expects to have 84.8 survivors on the average after 25% degradation, but the MET requirements for the unit at 75% capability are 92 personnel. Thus, a shortage of 7.2 personnel is expected as an average.

Degradation Level	12.5%	25.0%	37.5%
MET Requirements	104	92	76
Survivors (A)	112.9	96.8	80.6
Survivors (B)	105.9	90.8	75.6
Survivors (C)	98.9	84.8	70.6

Table B-1. Expected Survivors vs METs

Also, not unexpectedly based upon previous research with this unit, when the authorized strength remains constant, but the MET requirement is reduced by eight personnel in MOS 13B10, the capability response of the unit after degradation (line "D") is greater than for the full unit (line "A"). However, it should be noted that this improvement is not very large, and the unit is still constrained at higher levels of degradation by special skill requirements.

The results of the next area of research are less obvious because the interactions are more complex. This investigation considered the reduction of both the authorized strength and the METs at the same time. This corresponds to a unit being altered by the introduction of a new materiel system which requires less manpower than its predecessor, and thus its authorized strength is reduced along with its MET requirements. It was of interest to discover if a limit in personnel reductions could be reached beyond which critical skills would dominate the unit's capability to recover from degradation. In fact, as the results plotted in Figure B-2 show, personnel reductions caused relatively

B-8
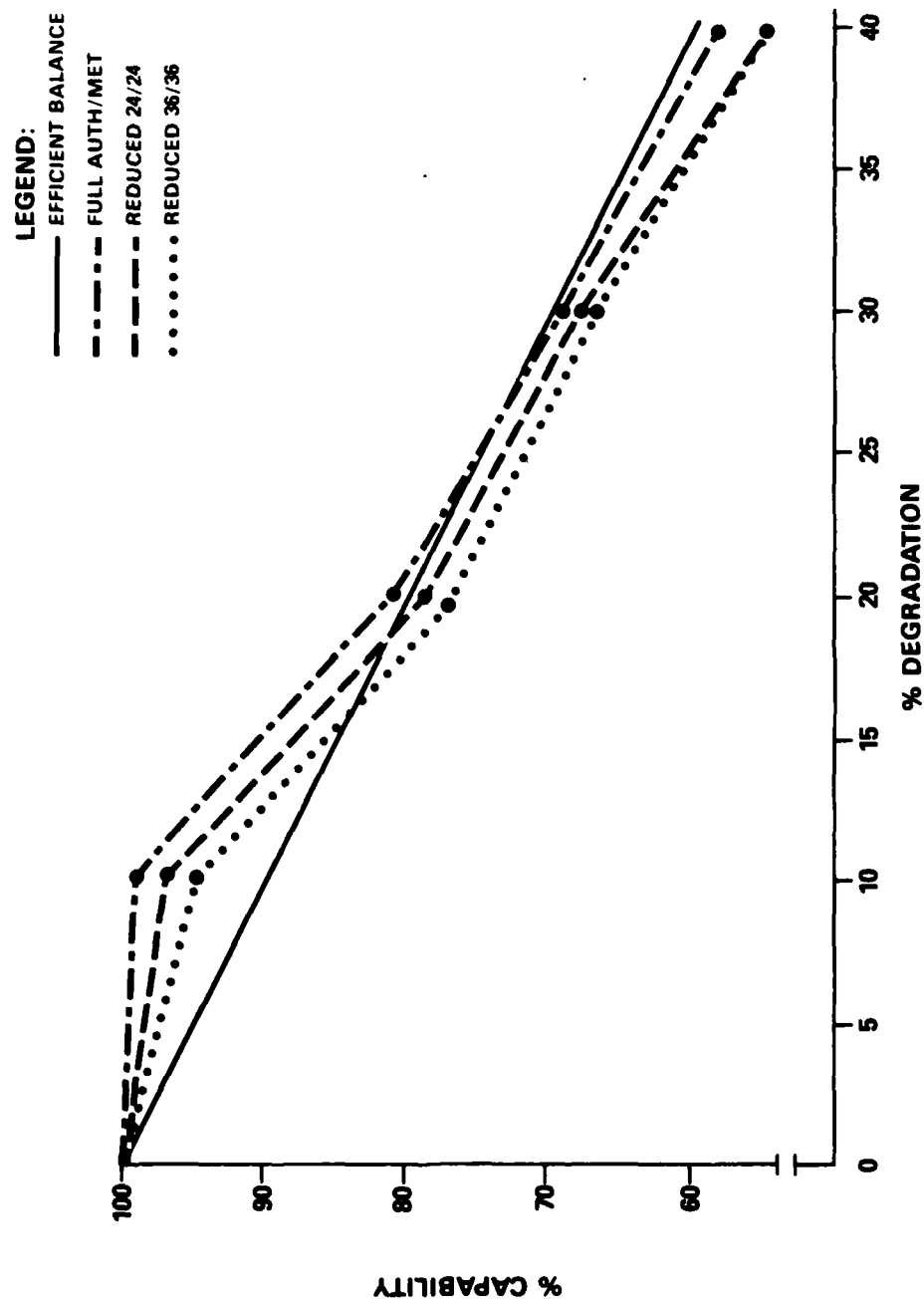
FIGURE B-2. CAPABILITY VS. DEGRADATION, VARYING AUTH. AND MET

little impact on this unit's resiliency. The line labeled "Full Auth/MET" refers to the Division-86 howitzer battery with all 129 authorized personnel and all 114 personnel required by the METs. The line labeled "Reduced 24/24" refers to the same unit with 24 crewmen (13B10) eliminated from the authorized strength and from the METs. The line labeled "Reduced 36/36" refers to the same unit with 24 crewmen (13B10), eight gunners (13B20), and four fire direction (13E10) personnel eliminated from the authorized strength and from the METs. Other intermediate reductions were examined too, but the results are so comparable that the graph would be too cluttered if all were shown. It should be recognized that these results may be much different for other units, especially a more "skill limited" unit such as a major headquarters which would be expected to lose much more capability than this battery.

The issue of substitutability was examined in some detail, but it became increasingly apparent that this factor is very unit and situationally dependent. An index of a unit's degree of substitutability is useful in this discussion. Although many different measures could be used, the following two will be developed and used in this report.

Let A be a unit of measure defined as

$$A = \frac{(S_{ij} \times S_j)}{N(N-1)} \quad , \, i \neq j; \, i=1, \, ..., \, K; \, j=1, \, ..., \, K \quad (5)$$

where S_{ij} is the number of personnel in skill i who can substitute for skill j, S_j is the number of personnel in skill j, N is the total number of personnel in the unit, and K is the number of skill groups in the Transfer Matrix. Using this definition for the Division-86 firing battery,

$$A = \frac{8,846}{129(128)} = 0.536$$

Let B be a unit of measure defined as

$$B = \frac{T_i}{K(K-1)} \quad , \, i=1, \, ..., \, K \quad (6)$$

where Ti is the number of skills into which skill i can transfer, and K is the total number of skill groups in the Transfer Matrix. The value of Ti can be determined directly from the "TRANS" column in the Transfer Matrix. For this same unit,

$$B = \frac{187}{25(24)} = 0.312$$

Several changes of substitutability were examined, but only two are reported here since they are illustrative of the other cases. The Division-86 Battery Personnel Transfer Matrix, which was developed in Section 3.2.1, is repeated here as Table B-2 for reference in the following discussion.

In the first case (line "F"), the substitutability of crewman (13B10) and the ammunition drivers (64C) are reduced so that each can only substitute for their own skill, grade, and duty position. For this case, A = 0.288 and B = 0.268. The large drop in index A (46%) reflects the large number of personnel in those two affected skills and in the skills into which they can substitute. The drop in index B is relatively modest (14%) since there are not many different skill lines affected by this change. The results of this change in substitutability can be seen in Figure B-3. The line marked (E) represents the full original unit. The line marked (F) is the unit with reduced substitutability as just described. It can be seen that there is essentially no change in the unit's capability response as a consequence of this substitutability change.

In the second example, four skills are selected for limited substitutability based upon their normal condition of having many possible substitutes available. These four skills are: #3 (BC's driver), #9 (Communication Chief), #10 (wire specialist), and #13 (Platoon Leader's driver). These skills are restricted to being substituted for only by their own skill group. For this case, A = 0.495 and B = 0.238. This time there is a very modest drop in index A (8%) reflecting that very few personnel are affected. The drop in B is much greater this time (24%) indicating that many more skill lines than before are affected. The results in this reduced substitutability can also be seen in Figure B-3. The line marked (G) is the same unit with this different

Table B-2. Division-86 Battery Personnel Transfer Matrix

SKILL			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	TRANS
01	BC	13E0	0	-	-	-	-	-	-	-	-	-	-	-	-	60	-	-	-	-	-	-	-	-	-	-	-	2
02	1SGT	13Y5	15	0	-	-	-	-	-	-	-	-	60	0	-	-	-	-	-	-	-	-	-	-	0	-	-	5
03	DVR	13B1	-	-	0	-	-	-	-	-	-	90	-	-	0	-	-	-	-	-	60	0	-	30	-	0	15	8
04	SPLSG	76Y4	-	30	-	0	0	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	30	30	0	15	8
05	ARM	76Y2	-	-	0	30	0	-	-	-	-	15	-	-	0	-	-	-	-	-	-	15	-	30	-	15	30	9
06	NBCSG	54E2	-	-	-	-	-	0	-	-	-	15	-	-	0	-	-	-	-	-	-	15	-	30	60	15	30	8
07	FSSGT	94B4	-	60	-	30	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	15	-	-	15	6
08	COOK	94B-	-	-	60	-	-	-	-	0	-	90	-	-	60	-	-	-	-	-	-	90	45	120	-	60	90	9
09	COMCH	31V3	-	-	-	-	-	-	30	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
10	WIRSP	36K-	-	-	-	-	-	-	-	-	-	0	-	60	-	-	-	-	-	-	60	60	30	120	-	45	90	8
11	PLLDR	13E0	0	-	-	-	-	-	-	-	-	-	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	3
12	PLSGT	13B4	-	30	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-	0	-	30	-	-	-	4
13	DVR	13B1	60	-	0	-	-	-	-	-	-	90	-	-	0	0	0	-	-	-	60	-	0	-	-	-	-	8
14	FDO	13E0	-	-	-	-	-	-	-	-	-	-	-	-	-	30	60	-	-	-	-	-	-	15	-	-	10	4
15	CHFDC	13E3	-	-	-	-	-	-	-	-	30	0	-	0	0	-	30	0	0	-	0	15	-	30	-	-	20	11
16	SRFDS	13E2	-	-	-	-	-	-	-	-	-	10	-	0	0	-	60	0	0	-	-	30	15	60	-	10	40	11
17	FDSP	13E1	-	-	0	-	-	-	-	-	-	20	-	30	0	-	-	30	0	-	0	0	-	0	-	20	0	10
18	CH/S	13B3	-	60	-	-	-	-	-	-	-	-	60	-	-	-	-	-	-	-	0	0	0	0	0	-	0	8
19	GUNR	13B2	-	-	0	-	-	-	-	-	-	20	-	0	0	-	0	-	-	0	15	0	0	0	-	-	0	11
20	CREW4	13B1	-	-	0	-	-	-	-	-	-	45	-	-	0	-	-	-	-	30	60	0	0	0	30	-	0	10
21	CREW3	13B1	-	-	-	-	-	-	-	-	-	90	-	30	-	-	-	-	-	0	0	-	0	30	-	45	20	8
22	AM CH	13B2	-	60	0	-	-	-	-	-	-	20	-	30	0	-	-	-	-	0	0	0	0	0	0	-	0	11
23	AM CH	13B3	-	-	0	-	-	-	-	-	-	-	-	-	0	-	-	-	-	0	60	0	0	0	0	0	0	7
24	AMMO	13B1	-	-	-	-	-	-	-	-	-	60	-	-	0	-	-	-	-	-	60	45	45	30	-	0	20	8
25	DVR	64C-	-	-	0	-	-	-	-	-	-	30	-	-	0	-	-	-	-	-	-	45	45	90	45	0	0	8
	SUBSTITUTES		3	7	13	2	1	0	1	1	2	16	5	8	13	4	3	2	2	6	9	15	15	18	9	14	18	187
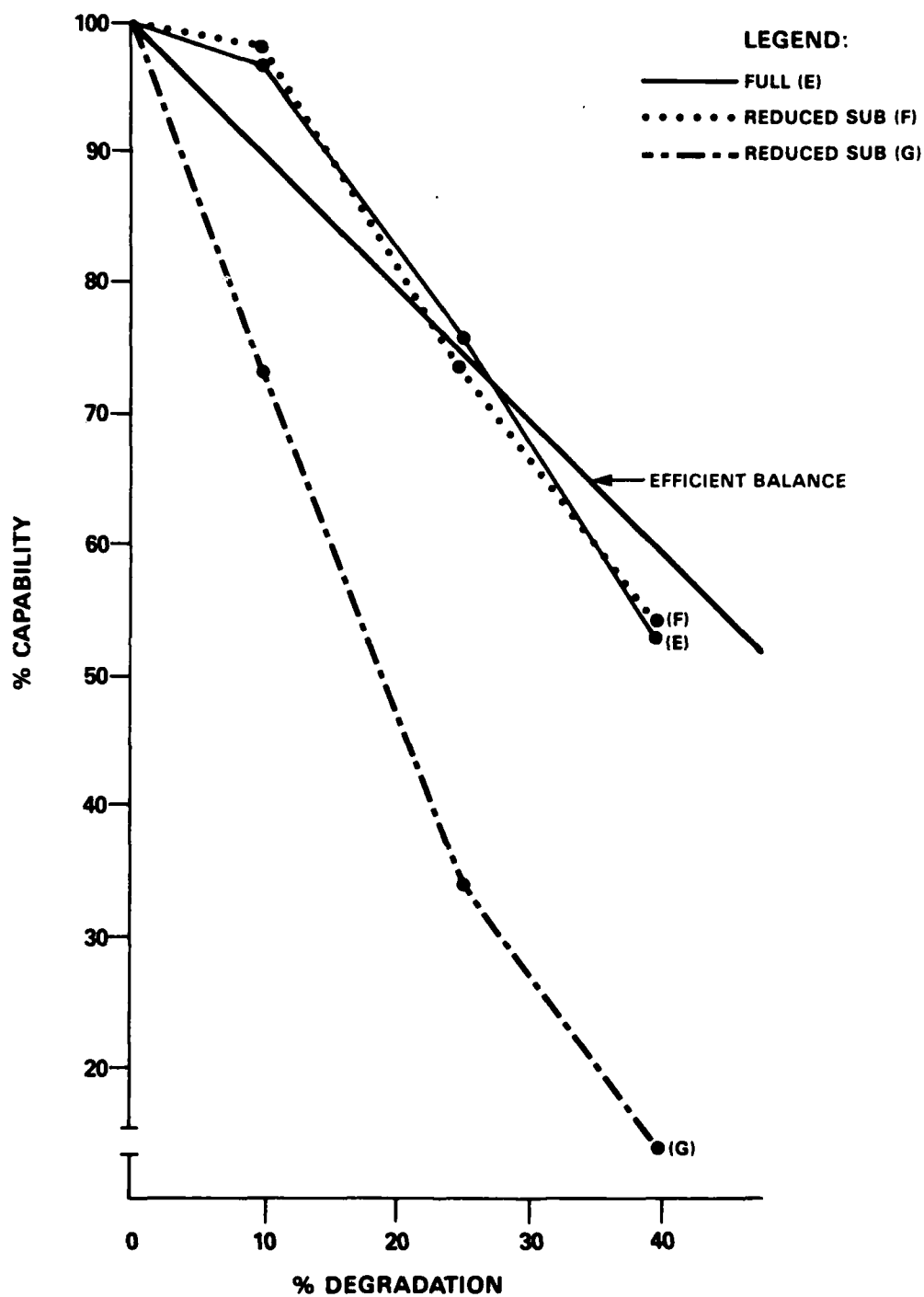
FIGURE B-3. CAPABILITY VS. DEGRADATION, VARYING SUBSTITUTABILITY

reduced substitutability. Not too surprisingly, this change has a major
impact on unit resiliency.

Although this research indicates that index B is somewhat more reflective
of the criticality of changes in substitutability, index A also has value in
certain situations. Index A is more sensitive to changes in large population
skill groups while index B is more sensitive to the number of skill groups
changed. Index B is unfortunately very sensitive to the degree of skill
aggregation that is used in establishing the substitutability matrix. It
should be noted that neither index reflects very well the criticality of the
situation where some skills have no substitutability. Such a condition is
highly likely to result in a skill limited unit.

APPENDIX C
DETAILED UNIT DESIGN EXAMPLE

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DETAILED UNIT DESIGN EXAMPLE

The purpose of this appendix is to present a detailed explanation of the Unit Design Methodology using the DSWS Firing Battery as an example. A summary of this analysis, stressing the results and their use in the AMORE application of this report, is presented in Section 3.3. The objective here is to present sufficient detail about the methodology, together with necessary tabular data and blank forms, for the user to be able to complete similar analyses without additional references. However, the user is encouraged to review the basic reference [Hannon, Robinson, and Stenstrom, 1983] for additional explanation, examples (especially materiel), and special insights.

C.1 DSWS FIRING BATTERY DESIGN ANALYSIS

The forms developed for use with this methodology are of two types. Design Form 1 is a four page checklist containing the procedures to be followed. It includes space to record the necessary calculation, priorities, and decisions which are made as part of the analysis. The pages of this form are numbered 1-1, 1-2, 1-3, and 1-4, and are titled Procedures Worksheet. The second type of forms are used to organize and record working data as part of the analysis. These forms are numbered 2P (Personnel), 3 (Prioritization), 4 (Prioritization Listing), and 5 (AMORE Initial Strength Entry).

C.1.1 Design Form 1-1

The Mission Essential Team (MET) structure and the Transfer Matrix for the battery personnel were developed as part of the baseline analysis in Section 3.2. They are repeated here in Tables C-1 and C-2, respectively, for reference and use in this analysis. Figure C-1 is the completed Design Form 1-1 for the DSWS Firing Battery design.

Table C-1. DSWS Battery Personnel METs

		MET STRUCTURE							
		TM1	TM2	TM3	TM4	TM5	TM6	TM7	TM8
01	BC	-	-	-	-	1	-	-	-
02	1 SGT	-	-	-	-	1	-	-	-
03	DR/RTO	-	-	-	-	1	-	-	-
04	XO	1	-	-	-	-	-	-	-
05	OPS NCO	1	-	-	-	-	-	-	-
06	SR FD SP	-	-	-	-	-	-	-	-
07	FD SP	2	-	-	-	-	-	-	-
08	NBC NCO	-	-	-	-	-	-	-	-
09	SPT PLSGT	-	-	-	-	-	-	1	-
10	DVR	-	-	-	-	-	-	1	-
11	FS SGT	-	-	-	-	-	-	-	-
12	COOK	-	-	-	-	-	-	-	-
13	SPL SGT	-	-	-	-	-	-	-	-
14	ARM	-	-	-	-	-	-	-	-
15	WIR SP	-	-	-	-	1	-	-	-
16	MT SGT	-	-	-	1	-	-	-	-
17	SP MECH	1	-	-	-	-	-	-	-
18	FA MECH	1	-	-	-	-	-	-	-
19	PLL/EQ	-	-	-	1	-	-	-	-
20	WV MECH	-	-	-	1	-	-	-	-
21	PLTLDR	-	1	-	-	-	1	-	-
22	PLTSGT	-	1	-	1	-	1	-	1
23	DR/RTO	-	1	-	1	-	1	-	1
24	GUN CH	1	1	1	1	1	1	1	1
25	ARV CH	1	1	1	1	1	1	1	1
26	GUNR	1	1	1	1	1	1	1	1
27	CREW	4	4	4	4	4	4	4	4
	TOTAL	13	10	7	12	11	10	9	9
	CUMULATIVE	13	23	30	42	53	63	72	81

Table C-2. DSWS Battery Personnel Transfer Matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	TRANS
01	BC	13E0	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	2
02	1SGT	13Y5	15	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	30	30	30	-	-	-	5
03	DR/RTO	13B1	-	-	0	-	-	0	-	-	-	0	-	-	-	-	90	-	-	-	-	-	-	-	30	-	90	60	30	6
04	XO	13E0	0	-	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	3
05	OPSNCO	13E3	-	30	-	30	30	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
06	SRFDSP	13E2	-	-	30	90	60	0	0	-	30	30	-	-	-	-	30	-	-	-	-	-	-	-	30	-	45	-	30	9
07	FDSP	13E1	-	-	30	-	-	15	0	0	-	30	-	-	-	-	30	-	-	-	-	-	-	-	30	-	90	-	30	8
08	NBCNCO	54E2	-	-	0	-	-	15	-	-	0	0	-	-	-	-	15	-	-	-	-	-	-	-	30	-	45	-	30	6
09	SPLTSG	13B4	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	45	30	-	30	-	-	-	5
10	DR	13B1	-	-	0	-	-	-	-	-	0	0	-	-	30	-	60	-	-	-	-	-	-	-	30	-	90	30	30	6
11	FSSGT	94B4	-	60	-	-	-	-	-	-	30	-	0	0	30	-	-	-	-	-	-	-	-	-	-	-	90	60	-	5
12	COOK	94B-	-	-	60	-	-	-	-	-	-	60	30	0	0	0	90	-	-	-	-	-	-	-	90	-	-	-	90	6
13	SPLSGT	76Y3	-	30	-	-	-	-	-	-	30	-	-	0	0	0	0	-	-	-	-	-	-	-	-	-	90	-	60	7
14	ARM	76Y2	-	-	0	-	-	-	-	-	-	0	-	0	30	0	15	-	-	-	-	-	-	-	30	-	90	-	60	8
15	WIRSP	36K1	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	15	0	-	-	30	-	-	-	90	4
16	MTSGT	63D4	-	60	-	-	-	-	-	-	45	-	-	-	-	-	-	60	0	0	30	0	-	-	-	-	-	-	-	6
17	SPMECH	63D-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	90	-	0	-	-	-	-	-	-	90	5
18	FAMECH	45D-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75	90	0	15	60	-	-	-	-	-	-	90	5
19	PLL/EQ	76C-	-	-	15	-	-	-	-	-	-	15	-	-	-	-	-	-	-	90	0	-	-	-	-	-	-	-	90	3
20	WVMECH	63B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90	90	15	0	-	-	-	-	-	-	90	4
21	PLTLDR	13E0	60	-	-	30	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0	-	-	-	4
22	PLTSGT	13B4	-	60	30	-	-	-	-	-	30	30	-	-	-	-	30	-	-	-	-	-	0	0	-	0	-	-	-	5
23	DR/RTO	13B1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	45	60	0	6
24	GUNCH	13B3	-	90	-	-	-	-	-	-	45	30	-	-	-	-	-	-	-	-	-	-	60	-	-	0	0	60	0	7
25	ARVCH	13B2	-	-	30	-	-	-	-	-	90	30	-	-	-	-	-	-	-	-	-	-	-	30	0	0	0	0	0	8
26	GUNR	13B2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	0	30	0	0	4
27	CREW	13B1	-	-	45	-	-	-	-	-	-	45	-	-	-	-	30	-	-	-	-	-	-	-	15	-	30	45	0	6
	SUBSTITUTES		3	7	11	4	4	2	2	0	7	11	1	1	2	1	10	2	3	3	6	3	6	6	10	5	12	8	17	147

DESIGN FORM 1-1 - PROCEDURES WORKSHEET - (PERSONNEL) OR MATERIEL (CIRCLE ONE)
CASE ____1_____   UNIT _DSWS_ FB   PAGE 1 OF 4   DATE _1 FEB 84_

1. ESTABLISH MISSION ESSENTIAL TEAM STRUCTURE

    FOR THE FOLLOWING MISSION ____SUSTAINED____OPERATIONS_____ (TABLE C-1)

2. ESTABLISH SUBSTITUTABILITY MATRIX. (TABLE C-2)

3. RECORD DESIGN CRITERIA:

    a. DESIGN GOAL TEAM LEVEL _____6_____

    b. DEGRADATION PROBABILITY _____0.25_____

    c. MAX TEAM GOAL _____8_____
        (Total Desired Number of MET Teams - With No Degradation)

    d. UNIT DESIGN ASSURANCE _____0.90_____

4. (DESIGN FORM 2P) OR FORM 2M - (PERSONNEL) OR MATERIEL (CIRCLE AS APPROPRIATE).

    a. FILL IN CASE, UNIT, PAGE, AND DATE AT TOP OF FORM.

    b. FILL IN LINE NUMBERS (COLUMN 1).

    c. FILL IN NAMES (COLUMN 2).

    d. FOR FORM 2P ONLY, FILL IN GRADE AND MOSC (COLUMNS 3 AND 4).

    e. ENTER THE DESIGN GOAL TEAM NUMBER (COLUMN 5 FORM 2P OR 2M). FOR EACH SKILL OR MATERIEL ITEM ENTER THE NUMBER
        REQUIRED AT THE DESIGN GOAL TEAM LEVEL (COLUMN 5).

    f. FOR EACH LINE ITEM WHICH HAS OTHER THAN ZERO IN COLUMN 3, COUNT THE NUMBER OF LINE ITEMS WHICH CAN
        TRANSFER INTO THE MISSION ESSENTIAL SKILL OR MATERIEL ITEM. ENTER THIS NUMBER IN COLUMN 6.

    g. FOR ALL LINE ITEMS (WHETHER MISSION ESSENTIAL OR NOT), COUNT THE NUMBERS OF SKILLS OR MATERIEL ITEMS
        INTO WHICH THE LINE ITEM CAN TRANSFER. ENTER THIS NUMBER IN COLUMN 7.

    h. ENTER ANY REMARKS IN COLUMN 8. IF YOU WISH TO MAINTAIN A BLANK MASTER THIS IS A GOOD STEP TO REPRODUCE
        WORKING COPIES.

    5. IDENTIFY ANY ZERO/ZERO CASES (AND ANY KNOWN INDEPENDENT CLUSTERS). IF THERE ARE NONE GO DIRECTLY TO PARAGRAPH 7.

        a. IDENTIFY ALL ZERO TRANSFERS IN COLUMN 6. FOR EACH CASE WHERE THE CORRESPONDING COLUMN 7 POTENTIAL
            TRANSFERS ARE ALSO ZERO, CIRCLE THE CORRESPONDING ITEMS IN COLUMN 5.

        b. COUNT THE NUMBER OF SUCH CASES, ADD ONE (UNLESS THE UNIT IS ALL ZERO/ZERO OR INDEPENDENT CLUSTER CASES)
            AND ENTER.

            _____

        c. BASED ON THE UNIT DESIGN ASSURANCE (PARA 3. d. ABOVE) ENTER THE ASSURANCE TABLES WITH THE NUMBER IN 5.b.
            ABOVE AND ENTER ASSURANCE _____

FIGURE C-1. DESIGN FORM 1-1, PROCEDURES WORKSHEET

The design criteria is recorded in paragraph 3. Because of the range of degradation of interest in this analysis, a mid-range point of 25% degradation probability was selected. Since one of the consequences of this new unit design will be a unit whose capability graph will plot on or above the equal balance line, at least until the design degradation point, this design value of degradation can be related to the earliest point where the unit can become nonresilient. In this case, the unit is being designed to be resilient until at least the 25% level of degradation. Since being able to form six of the eight METs is equivalent to 75% capability, six teams (or METs) are selected as the design goal level. Note that if six teams can be formed, the unit capability is equal to the level of unit survivors (75%) which means the unit is resilient.

The assurance selected for the design is 0.90 or 90%. This is the level of confidence which may be placed on the ability of the final design to meet the design goal team level. This assurance is achieved by requiring that in 90% of the AMORE iterations, the design team goal (6 METs) or more must be reconstituted. Since 30 iterations will be used, at least 27 must reach the design goal. Finally, the maximum team goal (8 METs) refers to the number of METs which the unit must be able to form when no degradation occurs. As will be the case in most situations, this equates to the total number of METs in the unit.

Paragraph 4 provides directions for establishing substitutabilty factors for each skill listed. Design Form 2P-Personnel is used to record required information. Design Form 2P, completed for this analysis, is at Figure C-2.

Paragraph 4e directs the listing in column 5 of the cumulative MET requirements for the design goal team (team six). Note that the MET structure in Table C-1 is not shown cumulatively, so the entries in that table need to be summed for each line before they are entered in column 5. The total requirements for team 6 are 63 personnel.

The values required by paragraph 4f can be taken from the transfer matrix. The bottom row of Table C-2, labeled "substitutes," is a count of the

1	2	3	4	5	6	7	8	9
				DESIGN	TRANSFERS POSSIBLE INTO THIS	TRANSFERS POSSIBLE FROM THIS	ZERO/ZERO	
LINE NUMBER	SKILL NAME	GRADE	MOSC	GOAL TEAM __6__	SKILL, IF RQD	SKILL, IF AVAIL	ADD ONE (FENCED)	REMARKS
1	BC	CPT	13EO	1	3	2		
2	1 SGT	E8	13Y5	1	7	5		
3	DVR	E3	13B1	1	11	6		
4	XO	LT	13EO	1	4	3		
5	OPS NCO	E6	13E3	1	3	4		
6	SR FD	E5	13E2	0	2	9		
7	FD SP	E4/3	13E1	2	2	8		
8	NBC NCO	E5	54E2	0	0	6		
9	SPT PS	E7	13B4	0	7	5		
10	DVR	E3	13B1	0	11	6		
11	FS SGT	E7	94B4	0	1	5		
12	COOK	E5/3	94B2/1	0	1	6		
13	SPLY	E6	76Y3	0	2	7		
14	ARM	E5	76Y2	0	1	8		
15	WIRSP	E4	36K1	1	10	4		
16	MT SGT	E7	63D4	1	2	6		
17	SP MECH	E6/3	63D3/1	1	3	5		
18	FA MECH	E5/4	45D2/1	1	3	5		
19	PLL/EQ	E5/4	76C2/1	1	6	3		
20	WV MECH	E5/4	63B1	1	3	4		
21	PLDR	LT	13EO	2	6	4		
22	P SGT	E7	13B4	3	6	5		

FIGURE C-2.   DESIGN FORM 2P — PERSONNEL

1	2	3	4	5	6	7	8	9
					TRANSFERS POSSIBLE INTO THIS	TRANSFERS POSSIBLE FROM THIS	~~ZERO/ZERO~~ ~~ADD ONE~~	
LINE NUMBER	SKILL NAME	GRADE	MOSC	DESIGN GOAL TEAM 6	SKILL, IF RQD	SKILL, IF AVAIL	~~(FENCED)~~	REMARKS
23	DVR	E3	13B1	3	10	6		
24	GUN CH	E6	13B3	6	5	7		
25	ARI CH	E5	13B2	6	12	8		
26	GUNR	E5	13B2	6	8	4		
27	CREW	E4/3	13B1	24	17	6		
TOTAL				63				

FIGURE C-2. DESIGN FORM 2P — PERSONNEL (CONTINUED)

number of substitutions which are possible from other skills into this skill. They need not be recorded on Design Form 2P if the skill is not required in the MET at the design goal level (i.e., if the entry in column 5 is 0) since those skills will have no priority anyway for add-ons.

Paragraph 4g is similar to the previous paragraph. The values for column 7 can be taken from the right-hand column of Table C-2, labeled "Trans." Its primary purpose is to help identify any cases where no items can be transferred to the MET item and where the MET item itself has no potential for transfers. These zero/zero cases are best treated by a separate procedure described in paragraphs 5 and 6 of Design Form 1-1 and 1-2. There are no zero/zero cases in this example. Accordingly, paragraphs 5 and 6 are skipped and the process moves directly to paragraph 7 on Design Form 1-2. Although zero/zero cases and independent clusters occur frequently with materiel, they are not as common with personnel. Accordingly, a separate example for this case will not be given in this report, and the user is referred to the basic reference for details.

C.1.2 Design Form 1-2

The completed Design Form 1-2 is shown at Figure C-3. Paragraph 7 presents the procedure for calculating a lower bound on personnel to be added to the MET to meet the design criteria. Paragraph 8 presents the procedure for calculating an upper bound. The final design add-ons to the MET will be somewhere between these two values. The entry for paragraph 7a is the total of the cumulative MET requirements for the design goal team (team six) and is equal to the sum of the entries in column 5 (63). The value calculated for paragraph 7d is shown to the nearest tenth but is rounded up to the next integer when recorded in 7f. This value is the lower bound. It is also recorded as directed on Design Form 5 for future use.

The actions required by paragraphs 8a, b, c, d, and e are self-explanatory. The Factor Tables (Section C.2) are used with paragraph 8f. The table on page C-31 is for a .9 design assurance. The number computed for paragraph 8e (13.5) is rounded up to the next higher integer (14) and used as an entry in the left column on page C-31. The corresponding value in the right column

~~6. ESTABLISH FENCED ADD ONS BASED ON ZERO/ZERO AND/OR INDEPENDENT CLUSTER CASES.~~

~~a. USE THE DEGRADATION FROM PARAGRAPH 3.b., THE ELEMENT ASSURANCE FROM PARAGRAPH 5.c.; AND THE REQUIRED NUMBER FOR EACH CIRCLED ZERO/ZERO AND INDEPENDENT CASE (COLUMN 5 OF FORM 2P OR 2M) TO ENTER THE REQUIREMENTS TABLES.~~

~~b. FIND THE REQUIRED NUMBER AT THE BEGINNING OF A ROW UNDER THE COLUMN LABELED "REQUIREMENT".~~

~~c. MOVE TO THE RIGHT TO FIND THE FIRST INSTANCE WHERE THE TABULAR ASSURANCE EQUALS OR EXCEEDS THE ENTERING ASSURANCE (FROM PARA 5.c., PREVIOUS PAGE).~~

~~d. MOVE UP THE COLUMN TO FIND THE ADD-ON HEADING THE COLUMN. RECORD THE ADD-ON ON THE APPROPRIATE LINE OF FORM 2P OR FORM 2M UNDER COLUMN 8.~~

~~e. REPEAT a. THROUGH d. FOR EACH ZERO/ZERO AND INDEPENDENT CLUSTER CASE.~~

7. ESTABLISH TRIAL LOWER BOUND FOR BRACKETING RUNS.

    a. ENTER THE TOTAL NUMBER OF PERSONNEL OR ITEMS REQUIRED FOR THE DESIGN GOAL TEAM (COLUMN 5 SUM) __63__.

    b. ENTER THE DEGRADATION PROBABILITY FROM PARAGRAPH 3.b. __0.25__.

    c. ENTER ONE MINUS THE DEGRADATION PROBABILITY __0.75__.

    d. MULTIPLY 7.a. BY 7.b. DIVIDE BY 7.c. AND ENTER __21.0__.

    e. IF NOT A WHOLE NUMBER, RAISE 7.d. TO THE NEXT HIGHER INTEGER ~~AND ADD TO ALL ZERO/ZERO AND INDEPENDENT CLUSTER REQUIREMENTS FROM COLUMN 8.~~

    f. RECORD THE LOWER BOUND TOTAL HERE AND AS THE CASE NUMBER HEADING COLUMN 20 IN DESIGN FORM 5. __21__.

8. ESTABLISH TRIAL UPPER BOUND FOR BRACKETING RUNS.

    ~~a. COUNT THE NUMBER OF ZERO/ZERO AND INDEPENDENT CLUSTER CASES _____.~~

    b. COUNT THE REMAINING REQUIRED STRENGTH (NON ZERO/ZERO OR INDEPENDENT CLUSTER ITEMS FROM THE DESIGN GOAL TEAM MET) __63__.

    c. COUNT THE REMAINING REQUIRED LINE ITEMS (NUMBER OF NON ZERO/ZERO OR NON CLUSTER ROWS IN SUBSTITUTION MATRIX) __27__.

    d. DIVIDE c. BY 2 __13.5__.

    e. ADD a. AND d. __13.5__.

    f. USING UNIT DESIGN ASSURANCE FROM 3.d., ENTER THE APPROPRIATE TABLE FROM ~~ANNEX D~~ APPENDIX C.2 WITH "NUMBER" FROM e. (14) (ROUNDED UP IF NECESSARY). RECORD "FACTOR" __2.433__.

    g. DIVIDE b. BY d. __4.6667__.

    h. MULTIPLY DEGRADATION PROBABILITY (7.b.) __0.25__ BY ONE MINUS THE DEGRADATION PROBABILITY (7.c.) __0.75__ BY g. AND RECORD ON TOP OF NEXT PAGE.

FIGURE C-3. DESIGN FORM 1-2, PROCEDURES WORKSHEET

("FACTOR") is identified (2.433) and recorded in paragraph 8f. The remaining parts of paragraph 8 are calculations to produce a middle bound and an upper bound to the MET add-ons.

C.1.3 Design Form 1-3

The completed Design Form 1-3 is shown at Figure C-4. Prioritization for add-ons is established through the procedure described in paragraph 9. Design Form 3 (Figure C-5) is used to record the calculations.

Paragraph 9c interprets real-world constraints and practicable interpretations of doctrine to limit what and how much of some skills can be added. These additions are to the design goal team as earlier recorded in column 5 (Figure C-2). For example, the design goal team already contains a Battery Commander and a First Sergeant, and it is not realistic to have more than one of each in such a unit, so the entries for those two line numbers in column 11 are both zero indicating that no more may be added.

Paragraph 9d does not cause any entries to be made in column 12 in this example since there are no zero/zero cases. As directed by paragraph 9e, X's are placed in column 13 to identify the lines which have no requirement in the design MET (zeros in column 5). They are identified here because they will not be part of the prioritization process which follows.

Calculations are now made for the lower bound and upper bound add-ons for each skill, and are recorded in columns 17 and 18 respectively. For column 17, this is the lower bound (21) divided by the total personnel on the design goal team (63) times the MET requirement for each line (entries in column 5). For example for line number 1, (21) divided by (63) multiplied by (1) equals .3.

The priorities for add-ons to each line are now established as directed by paragraph 9h. Using column 6 (Figure C-2), the line with the fewest available skills to transfer to it is given the highest priority for add-ons. Skills #7 and 16 each have only two other skills which can be transfered to their position and thus are the highest priority for add-ons. There are no

   i. __.8750__ MULTIPLY THE SQUARE ROOT OF THIS NUMBER BY d., THEN BY f., AND THEN DIVIDE BY 7.c. TO GET THE VARIABILITY ADD-ON ____41.0____.

   j. RAISE i. TO THE NEXT HIGHER POWER OF 2 (2, 4, 8, 16, 32, 64, ETC.)____64____.

   k. ADD j. DIVIDED BY 2 ____32____ TO 7.f. ____21____ TO GET MIDDLE BOUND CASE NUMBER ____53____. RECORD ALSO AT THE TOP OF COLUMN 29 ON FORM 5 AS THE CASE NUMBER.

   l. ADD j. ____64____ TO 7.f. ____21____ TO GET UPPER BOUND CASE NUMBER ____85____. RECORD ALSO AT THE TOP OF COLUMN 30 ON FORM 5 AS THE CASE NUMBER.

9. ESTABLISH PRIORITIES (DESIGN FORMS 2P) OR 2M AND 3)

   a. FILL IN CASE, UNIT, PAGE, AND DATE AT TOP OF FORM 3.

   b. FILL IN LINE NUMBERS (COLUMN 10 OF FORM 3).

   c. IDENTIFY ANY CONSTRAINTS ON POSSIBLE ADD-ONS UNDER COLUMN 11 OF FORM 3.

   d. COPY COLUMN 8 UNDER COLUMN 12.

   e. PUT AN X UNDER COLUMN 13 FOR EACH LINE NUMBER WITH NO DESIGN MET REQUIREMENT.

   f. UNDER COLUMN 17, ENTER (TO THE NEAREST TENTH WHERE AN ADD-ON IS NOT CONSTRAINED UNDER COLUMN 11) THE LOWER BOUND (7.f.) DIVIDED BY THE MET TOTAL (7.a.) TIMES THE MET REQUIREMENT FOR EACH LINE.

   g. UNDER COLUMN 18, ENTER (TO THE NEAREST TENTH WHERE AN ADD-ON IS NOT CONSTRAINED UNDER COLUMN 11) THE UPPER BOUND (8.1.) DIVIDED BY THE MET TOTAL (7.a) TIMES THE MET REQUIREMENT FOR EACH LINE.

   h. UNDER COLUMN 14, USE COLUMN 6, THE LIMITS OF COLUMNS 11-13, AND THE IMPLIED REQUIREMENTS OF COLUMNS 17 AND 18 TO ESTABLISH PRIORITIES FOR SKILLS OR ITEMS TO BE ADDED

   i. IF NOT APPROPRIATE TO ADD THE PRIMARY SKILL OR ITEM, ESTABLISH ALTERNATIVE SUBSTITUTES UNDER COLUMN 15. RECORD THE SUBSTITUTE LINE NUMBER RATHER THAN A PRIORITY NUMBER UNDER COLUMN 15.

10. APPLY PRIORITIES. (DESIGN FORMS 3 AND 4.)

   a. FILL IN HEADING OF DESIGN FORM 4.

   b. ON DESIGN FORM 4, NUMBER THE PRIORITIES UNDER COLUMN 21.

   c. UNDER COLUMN 22 ASSOCIATE WITH EACH PRIORITY (FROM b.) A LINE NUMBER SKILL OR MATERIEL ITEM TO BE COVERED IN THE ADD-ON.

   d. UNDER COLUMN 23 SHOW THE LINE NUMBER TO BE ASSIGNED (COULD BE A SUBSTITUTE).

   e. UNDER COLUMN 24 SHOW HOW MANY OF d. ARE TO BE ADDED.

   f. DRAW A LINE WHEN THE ACCUMULATION UNDER COLUMN 24 SATISFIES THE LOWER BOUND.

   g. DRAW A LINE WHEN THE ACCUMULATION UNDER COLUMN 24 SATISFIES THE UPPER BOUND.

FIGURE C-4. DESIGN FORM 1-3, PROCEDURES WORKSHEET

DESIGN FORM 3 - PRIORITIZATION - (PERSONNEL) OR MATERIEL (CIRCLE ONE)

CASE ___1___ UNIT DS&JS FB PAGE _1_ OF _2_ DATE 1 FEB 84

10	11	12	13	14	15	16	17	18	19	20
		E X C L U S I O N S				P R I O R I T I E S				
LINE NUMBER	first: MAXIMUM ADD-ON	second: FENCED (COLUMN 8)	third: NOT ON NET	first: LEAST CAN SUBS FOR	second: CAN SUBS FOR MOST	third: AVAIL OF LINE ITEM	fourth: LOWER BOUND	fifth: UPPER BOUND	sixth: USER CHOICE	REMARKS
1	0			3	L4		.3	1.3		
2	0			13	L13	U11 (2)	.3	1.3		
3	1			17		U27	.3	1.3		
4	1			8	L5		.3	1.3		
5	1			7	L6	U7	.3	1.3		
6	2		X							
7	3			2	L6	U7 (2)	.7	2.7		
8	1		X						①	
9	1		X							
10	1		X							
11	1		X						①	
12	5		X						⑤	
13	1		X						①	
14	1		X						①	
15	1			15		U8,U12	.3	1.3		
16	0			1	U17		.3	1.3		
17	2			4	L17	U20	.3	1.3		
18	2			5	L18	U20	.3	1.3		
19	1			12	L4	U19	.3	1.3		
20	2			6	L8		.3	1.3		
21	0			10	L24		.7	2.7		
22	1			11	L24		1.0	4.0		

FIGURE C-5. DESIGN FORM 3 — PRIORITIZATION

10	11	12	13	14	15	16	17	18	19	20
		EXCLUSIONS			PRIORITIES					
LINE NUMBER	first: MAXIMUM ADD-ON	second: FENCED (COLUMN 8)	third: NOT ON MET	first: LEAST CAN SUBS FOR	second: CAN SUBS FOR MOST	third: AVAIL OF LINE ITEM	fourth: LOWER BOUND	fifth: UPPER BOUND	sixth: USER CHOICE	REMARKS
23	1			16	(4) U12		1.0	4.0		
24	2			9	(2) L25	U26,U22 U9,U22	2.0	8.1		
25	2			18	(8) U27		2.0	8.1		
26	2			14	U3,U10,U23	(5) U27	2.0	8.1		
27	40			19	(25) U27,U15		8.0	32.4		

FIGURE C-5.   DESIGN FORM 3 — PRIORITIZATION (CONTINUED)

standard tie breakers for this situation. Once a final design is determined, the "cut-off" skills may deserve a sensitivity analysis to determine if there is any difference in unit resiliency between the last skill included and the first skill omitted. In a similar manner, the prioritization process is completed for all skills which are required in the MET.

Before applying those priorities, one additional constraint has been added for this example. The entries in column 19 reflect user decisions that the skills indicated, which are not part of the MET, will be in the final design at the level shown. In other words, if they are not added in by the prioritization process, they will replace the same number of the lowest priority skills which would otherwise be added. The decision on these skills (NBC NCO, Food Service Sergeant, Cooks, Supply Sergeant and Armorer) acknowledges that they are all needed in the unit for effective peacetime operations and desirable for efficient combat operations even though they are not identified as mission essential. Thus, it is not reasonable to design the unit without them.

A prioritized list of add-ons is established in response to paragraph 9i. Columns 15 and 16 are used to record the solutions and Design Form 4 is used to record the same information in a more usable format for the analysis (Figure C-6).

The first priority listed in column 14 is for Skill 16 (Maintenance Supervisor). Skill 16 is constrained from more add-ons as reflected in column 11 because one is already present in the MET. However, from the Transfer Matrix (Table C-2), it can be determined that Skills 17 and 18 are allowable substitutes. From column 11, two of each of those skills are available. From the last column (right side) in Table C-2, select the allowable substitute which can transfer to the most other skills. In this case, both Skills 17 and 18 can transfer to five other skills so either may be selected (Skill 17 was selected for this example). The entry in column 17 rounded up to the next higher integer (.3 rounded to 1) is the add-on requirement for the lower bound. Thus, one of Skill 17 was selected to fill the lower bound add-on requirement for Skill 16. This is recorded in column 15 with "L17" where L indicates it was part of the lower bound add-on. This decision is also

C-14

21	22	23	24	25
PRIORITY NUMBER	LINE NUMBER REQUIRED	LINE NUMBER ASSIGNED	FINAL ADD ONS (INCLUDING COLUMN 8)	REMARKS (CUMULATIVE)
1	16	17	1	1
2	7	6	1	2
3	1	4	1	3
4	17	17	1	4
5	18	18	1	5
6	20	18	1	6
7	5	6	1	7
8	4	5	1	8
9	24	25	2	10
10	21	24	1	11
11	22	24	1	12
12	19	14	1	13
13	2	13	1	14 (+7 "SPECIAL" SKILLS = 21)
2	7	7	2	16
4	17	20	1	17
5	18	20	1	18
7	5	7	1	19
9	24	9	1	20
9	24	22	1	21
9	24	26	2	23
12	19	19	1	24
13	2	11	1	25

LOWER BOUND (marked to the left of priority 13 row)

FIGURE C-6.   DESIGN FORM 4 — PRIORITIZATION LISTING

21	22	23	24	25
PRIORITY NUMBER	LINE NUMBER REQUIRED	LINE NUMBER ASSIGNED	FINAL ADD ONS (INCLUDING COLUMN 8)	REMARKS (CUMULATIVE)
14	26	3	1	26
14	26	10	1	27
14	26	23	1	28
14	26	27	5	33
15	15	8	1	34
15	15	12	1	35
16	23	12	4	39
17	3	27	2	41
18	25	27	8	49
19	27	27	4	53
19	27	27	21	74
19	27	15	1	75

MIDDLE BOUND ← (arrow pointing to row 53)

UPPER BOUND ← (arrow pointing to row 75)

FIGURE C-6. DESIGN FORM 4 — PRIORITIZATION LISTING (CONTINUED)

recorded on the first line of Design Form 4 in accordance with the instructions in paragraph 10 of Design Form 1-3.

The second priority is Skill 7 (Fire Direction Specialist). There are add-ons available for Skill 7 but Skills 5 and 6 are available substitutes. Skill 5 has four transfers, Skill 6 has nine transfers, and Skill 7 has 8 transfers. Therefore, Skill 6 (Senior Fire Direction Specialist) is selected to fill the one required add-on.

A different example is illustrated with priority 9 which is for two of Skill 24 (Gun Chiefs). This is the first requirement which is greater than one. Skill 25 is determined to be the best substitute and, since two of those personnel were available, both requirements are satisfied by that skill. The number 2, in parenthesis above the L25 entry in column 15, indicates that selection of two personnel.

This process continues until sufficient add-ons are selected to satisfy the lower bound. The line after priority 13, labeled "Lower Bound" on Figure C-6, separates the lower bound requirement from the higher requirements. That requirement of 21 add-ons is satisfied by the first 14 skills listed plus the additional seven skills previously discussed as necessary in the final design. Note that two of those nine identified skills are already part of the lower bound add-ons so that only seven additional are required.

To satisfy the upper bound add-on, the process is started over again based now on the requirements in column 18 instead of 17 (Figure C-5). The first priority, Skill 16, has no available substitutes and so is passed. The next priority is Skill 7 (Fire Direction Specialist). Column 18 indicates a requirement for two additional individuals to meet this skill requirement for the upper bound. At this point, Skills 5 and 6 are no longer available, but Skill 7 still has three personnel available for add-on. Therefore, two of Skill 7 are selected to fill the requirement. Add-ons are now recorded (in column 16) with a "U" to indicate they are part of the upper bound. They are also recorded on Design Form 4. The process continues until the upper bound is reached or, as in this example, the available resources are exhausted.

C-17

Lines have been placed and labeled on Figure C-6 to indicate the location of the middle bound and the upper bound of add-ons.

In summary, the general procedure for determining the prioritized list of add-ons is:

- Identify the line number for the next priority to be assigned.

- Identify the potential substituting skills which have the most transfers.

- Check the needs of the pro rata share to be earmarked (columns 17 and 18 of Design Form 3).

- Check the allocation remaining for the skill to be assigned by considering what has been used up and the limits in column 11.

- Stop when assignments allocated total the upper bound add-on.

C.1.4 Design Form 1-4

The completed Design Form 1-4 is shown at Figure C-7. The data which has been developed is organized, as directed by paragraph 11, for efficient use with the AMORE software to select the unit design.

Design Form 5 (Figure C-8) is used to record the initial strengths of all cases to be tested and their results. Column 27 lists the design goal team which was recorded earlier in column 5. Columns 28, 29, and 30 reflect the add-ons which were previously selected. The circled numbers indicate changes from the MET initial strength (column 27). The totals of personnel initial strength for each case are recorded on page C-21. Provisions are also made there to record the results of the AMORE iterations in terms of the number of times each team could be formed (at a maximum) for each case.

Paragraph 12 provides the steps for obtaining a tentative solution. The development of a solution for this example proceeds as follows. Since 30 replications or trials are made for each case, the criteria for success is when six or more teams can be formed on 27 or more of the replications. The objective is to find the minimal design which meets that test criteria.

11. DEVELOP AMORE INITIAL STRENGTH ENTRIES TO REPRESENT EACH DEVELOPED CASE (DESIGN FORM 5).

   a. FILL IN HEADING INFORMATION.

   b. LIST THE DESIGN MET REQUIREMENTS BY LINE NUMBER UNDER COLUMN 26.

   c. ENTER THE DESIGN GOAL STRENGTH FROM COLUMN 5 UNDER COLUMN 27.

   d. APPLY THE PRIORITIES FROM DESIGN FORM 4 TO COLUMN 27 TO OBTAIN THE LOWER BOUND CASE INITIAL STRENGTH (COL 28).

   e. APPLY THE PRIORITIES FROM DESIGN FORM 4 TO COLUMN 28 TO OBTAIN THE MIDDLE BOUND CASE INITIAL STRENGTH (COL 29).

   f. APPLY THE PRIORITIES FROM DESIGN FORM 4 TO COLUMN 29 TO OBTAIN THE UPPER BOUND CASE INITIAL STRENGTH (COL 30).

   g. CIRCLE THE ENTRIES WHICH ARE CHANGED FROM COLUMN 27 BY PRIORITY ADD-ONS. PLACE THE PRIORITY NUMBER TO THE UPPER RIGHT.

   h. PLACE THE TOTAL INITIAL STRENGTH AFTER THE LAST LINE ENTRY UNDER COLUMNS 28 THROUGH 30.

12. DEVELOP SUBSEQUENT CASES BASED ON THE AMORE RUN RESULTS.

   a. CIRCLE "MAKE" OR "FAIL" ACCORDING TO THE RUN OUTCOMES FOR EACH CASE WHICH EITHER MET THE DESIGN CRITERIA OR FAILED TO MEET IT.

   b. USING PRIORITIES DEVELOPED ON DESIGN FORM 4, SPLIT SUBSEQUENT BRACKETS BY DEVELOPING NEW CASES WITH LESS ADD-ONS THAN A "MAKE" RESULT AND MORE ADD-ONS THAN A "FAIL" RESULT UNTIL A CHANGE OF ONE ADD-ON HAS BEEN MADE.

   c. EITHER JUDGE SUCCESS BY THE LEAST ADD-ON THAT MET THE DESIGN CRITERIA OR DEVELOP ALTERNATIVES UNDER THE REMAINING COLUMNS.

   d. SIGNIFICANT SURPLUSSES SHOWING UP IN THE ACCEPTED RUN CAN BE USED TO ATTEMPT TO ESTABLISH A NEW BOUNDING BRACKET TO REDUCE REQUIRED STRENGTH FURTHER.

13. TEST THE ACCEPTED STRENGTH AGAINST THE REQUIREMENTS OF THE FULL MET WITH ZERO DEGRADATION.

   a. TWO ITERATIONS ONLY NEED BE RUN.

   b. IF THE BEST CASE FAILS TO MEET THE FULL MET, ADJUST THE COMPOSITION (OR, IF NECESSARY THE STRENGTH) OF THE BEST CASE.

FIGURE C-7. DESIGN FORM 1-4, PROCEDURES WORKSHEET

CASE ___1___   UNIT DSWS FB   PAGE _1_ OF _2_   DATE 1 FEB 84

26 LINE NUMBER	27 DESIGN GOAL STRENGTH (COLUMN 5)	28 LOWER BOUND CASE 21 MAKE/(FAIL)?	29 MIDDLE BOUND CASE 53 (MAKE)/FAIL?	30 UPPER BOUND CASE 85 MAKE/FAIL?	31 CASE 37 (MAKE)/FAIL?	32 CASE 29 (MAKE)/FAIL?	33 CASE 25 MAKE/(FAIL)?	34 CASE 27 (MAKE)/FAIL?	35 CASE 26 MAKE/(FAIL)?	36 CASE ___ MAKE/FAIL?
1	1	1	1	1	1	1	1	1	1	
2	1	1	1	1	1	1	1	1	1	
3	1	1	(2)	(2)	(2)	1	1	1	1	
4	1	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	
5	1	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	
6	0	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	
7	2	2	(5)	(5)	(5)	(5)	(4)	(5)	(5)	
8	0	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
9	0	0	(1)	(1)	(1)	(1)	0	(1)	0	
10	0	0	(1)	(1)	(1)	0	0	0	0	
11	0	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
12	0	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	
13	0	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
14	0	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	
15	1	1	1	(2)	1	1	1	1	1	
16	1	1	1	1	1	1	1	1	1	
17	1	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	
18	1	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	
19	1	1	(2)	(2)	(2)	1	1	1	1	
20	1	1	(3)	(3)	(3)	(3)	(3)	(3)	(3)	
21	2	2	2	2	2	2	2	2	2	
22	3	3	(4)	(4)	(4)	(4)	3	3	3	

FIGURE C-8. DESIGN FORM 5 — AMORE INITIAL STRENGTH ENTRY

CASE __1__   UNIT _DS&S FB_   PAGE _2_ OF _2_   DATE _1 FEB 84_

26	27	28	29	30	31	32	33	34	35	36
	DESIGN GOAL STRENGTH	LOWER BOUND CASE 21	MIDDLE BOUND CASE 53	UPPER BOUND CASE 85	CASE 37	CASE 29	CASE 25	CASE 27	CASE 26	CASE ___
LINE NUMBER	(COLUMN 5)	MAKE/(FAIL)?	(MAKE)/FAIL?	MAKE/FAIL?	(MAKE)/FAIL?	(MAKE)/FAIL?	MAKE/(FAIL)?	(MAKE)/FAIL?	MAKE/(FAIL)?	MAKE/FAIL?
23	3	3	(4)	(4)	(4)	3	3	3	3	
24	6	(8)	(8)	(8)	(8)	(8)	(8)	(8)	(8)	
25	6	(8)	(8)	(1)	(8)	(8)	(8)	(8)	(8)	
26	6	6	(8)	(8)	(8)	(7)	6	6	6	
27	24	24	(43)	(64)	(27)	24	24	24	24	
TOTAL	63	84	116	148	100	92	88	90	89	

RESULTS OF AMORE ITERATIONS (30 EACH)

TEAM 8		28	–	2				
7		2	–	23	4	2	6	2
DESIGN GOAL → 6	20		–	5	24	21	21	23
5	9		–		2	7	3	5
4			–					
3	1		–					
2			–					
1			–					
0			–					

FIGURE C-8. DESIGN FORM 5 — AMORE INITIAL STRENGTH ENTRY (CONTINUED)

The middle bound case (column 29) is tested first and it succeeds. Therefore, the lower bound case is tried next to create a bracket. The upper bound case can now be discarded since the middle bound is a "smaller upper bound". The lower bound case fails.

The next step is to develop the case half way between the lower and middle bounds. This case, labeled 37, is shown in column 31. The prioritization listing in Figure C-6 is used to identify changes in initial strength which are reflected in column 31. This case succeeds and so becomes the new upper bound.

Again splitting the two bounds half way, case 29 (column 32) is developed. This case succeeds and so becomes the new upper bound.

Again splitting the two bounds (cases 29 and 21), case 25 is developed (column 33). This case fails and so becomes the new lower bound.

The two bounds are again split to create case 27 (column 34). This case succeeds exactly.

Case 26, which drops the lowest priority add-on from Case 27, is tested and it fails. Therefore, Case 27 is tentatively identified as the unit design.

Following paragraph 13 (Figure C-7), the unit design is tested to insure it can form all METs with zero degradation. Only two replications are tested and the design is successful. Actually, the solution is unique since there is no random degradation, but the software is not designed to make single runs so a minimum of two are made.

The new design is shown in the right hand column of Table C-3. The design shown is not adjusted to show revised duty positions which would be part of an actual design analysis, but is just intended to show the new skill requirements. The final test described in the preceeding paragraph verifies that these skill authorizations can substitute to fill all MET requirements.

Table C-3. Personnel, DSWS Unit Design

Section	Skill	Rank/Grade	MOS	Now	New
BTRY	BTRY CDR	CPT	13E00	1	1
	FIRST SGT	E-8	13Y5M	1	1
	DR/RTO	E-3	13B10	1	1
BTRY OPNS	BTRY XO	LT	13E00	1	2
	OPNS NCO	E-6	13E30	1	2
	SR FD SP	E-5	13E20	1	2
	NBC NCO	E-5	54E20	1	1
	FD SP	E-4	13E10	2	4
	DR/RTO	E-3	13E10	1	1
SPT PLT	PLT SGT	E-7	13B40	1	1
	VEH DR	E-3	13B10	1	0
	FOOD SVC SGT	E-7	94B40	1	1
	1ST COOK	E-5	94B20	1	1
	COOK	E-4/3	94B10	4	4
	SPLY SGT	E-6	76Y30	1	1
	ARMORER	E-5	76Y20	1	1
	TAC WIRE SP	E-4	36K10	2	1
	MAINT SGT	E-7	63D40	1	1
	SP FA AUTO MECH	E-6	63D30	1	1
	FA WPNS MECH	E-5	45D20	1	1
	PLL CLK	E-5	76C20	1	1
	EQ MAINT CLK	E-4	76C10	1	0
	FA WPNS MECH	E-4	45D10	1	2
	PWR GEN/WV MECH	E-4	63B10	1	3
	SP FA AUTO MECH	E-3	63D10	1	2
2-FIRE PLT	PLT LDR	LT	13E00	2	2
	PLT SGT	E-7	13B40	2	2
	GUNN SGT	E-7	13B40	2	1
	DR/RTO	E-3	13B10	4	3
8-FIRE UNITS	GUN CH	E-6	13B30	8	8
	ARV CH	E-5	13B20	8	8
	GUNNER	E-5	13B20	8	6
	ARV DR/CANN	E-4	13B10	8	8
	ASST GUN	E-4	13B10	8	8
	SPH DR/CANN	E-4	13B10	8	4
	CANN/AMMO HDLR	E-3	13B10	8	4
				96	90

The effect of these unit design changes on unit capability as a function of degradation can be seen in Figure C-9. The "actual" line shown is the unit response calculated earlier as the baseline response and shown in Figure 3-2. The "design" line shown is the corresponding response from this new design. Although the capability is somewhat lower at the level of 12.5% degradation, it is still above the equal balance line. It is designed to be right at or above the ideal line at 25% which is a noticeable improvement over the actual case. At 37.5% degradation, capability is below the equal balance line but well above the actual case. In summary, this new response curve is much better than the actual design and requires less personnel.

These design results are achieved with fewer people than the actual authorizations (reduction of six). Key savings (13) are possible in 13B skill positions. The major expense is for an additional officer and four fire direction (13E) skill positions. Four additional mechanics are also called for although the Equipment Maintenance Clerk (76C) position could be eliminated. Also, one of the 36K wireman positions could be eliminated.

The maintenance skills were earlier identified as critical, primarily because of the limited number of skills which could substitute for them. We must be careful not to overemphasize this situation since it was not the result of increased requirement caused by the new materiel system, but rather because of a changed concept on providing the maintenance support (battalion aggregation versus battery dispersion). This problem can be resolved in other ways than system design changes to the DSWS.
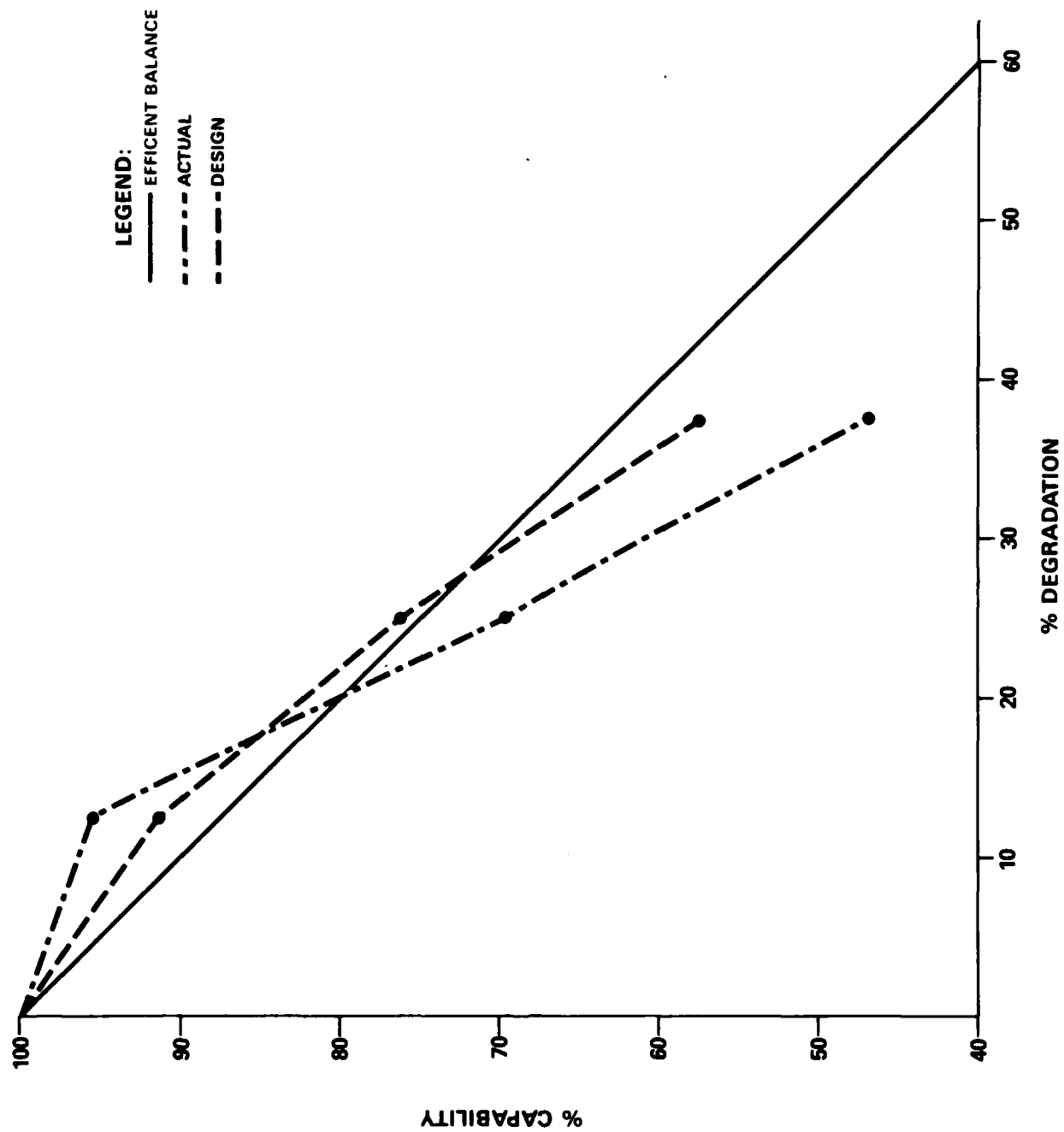
FIGURE C-9. CAPABILITY VS. DEGRADATION, DSWS DESIGN CASE

LEGEND:
——— EFFICENT BALANCE
—··—··— ACTUAL
—·—·— DESIGN

% DEGRADATION

% CAPABILITY

C.2 FACTOR TABLES

Pages C-27 through C-36 contain tabular data required by the procedures of Design Form 1-2 (paragraph 8f) to calculate the upper bound add-on quantity.

C.3 UNIT DESIGN FORMS

Pages C-37 through C-45 contain blank copies of the unit design forms for use by the reader as desired.

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .86 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
1	0.86000	1.080
2	0.92736	1.456
3	0.95097	1.655
4	0.96300	1.786
5	0.97029	1.886
6	0.97518	1.963
7	0.97868	2.028
8	0.98132	2.082
9	0.98338	2.130
10	0.98503	2.171
11	0.98638	2.209
12	0.98751	2.240
13	0.98847	2.272
14	0.98929	2.299
15	0.99000	2.327
16	0.99062	2.350
17	0.99117	2.372
18	0.99166	2.393
19	0.99209	2.413
20	0.99249	2.432
21	0.99284	2.449
22	0.99317	2.466
23	0.99346	2.482
24	0.99374	2.497
25	0.99399	2.511
26	0.99422	2.525
27	0.99443	2.538
28	0.99463	2.551
29	0.99481	2.563
30	0.99499	2.575
31	0.99515	2.586
32	0.99530	2.597
33	0.99544	2.608
34	0.99557	2.618
35	0.99570	2.628
36	0.99582	2.637
37	0.99593	2.646
38	0.99604	2.655
39	0.99614	2.664
40	0.99624	2.672
41	0.99633	2.681
42	0.99642	2.689
43	0.99650	2.697
44	0.99658	2.704
45	0.99665	2.711
46	0.99673	2.719
47	0.99680	2.726
48	0.99686	2.733
49	0.99693	2.740
50	0.99699	2.746

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .87 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
	0.87000	1.126
1	0.93274	1.496
2	0.95464	1.692
3	0.96578	1.822
4	0.97253	1.919
5	0.97706	1.997
6	0.98030	2.060
7	0.98274	2.114
8	0.98465	2.161
9	0.98617	2.202
10	0.98742	2.238
11	0.98846	2.272
12	0.98935	2.301
13	0.99010	2.330
14	0.99076	2.356
15	0.99133	2.380
16	0.99184	2.402
17	0.99229	2.423
18	0.5 70	2.442
19	0.9 6	2.461
20	0.99339	2.478
21	0.99369	2.494
22	0.99396	2.510
23	0.99421	2.525
24	0.99445	2.539
25	0.99466	2.553
26	0.99486	2.566
27	0.99504	2.578
28	0.99521	2.591
29	0.99537	2.602
30	0.99552	2.614
31	0.99566	2.624
32	0.99579	2.635
33	0.99591	2.645
34	0.99603	2.654
35	0.99614	2.664
36	0.99624	2.673
37	0.99634	2.682
38	0.99644	2.691
39	0.99653	2.699
40	0.99661	2.707
41	0.99669	2.715
42	0.99677	2.723
43	0.99684	2.731
44	0.99691	2.738
45	0.99698	2.745
46	0.99704	2.752
47	0.99710	2.759
48	0.99716	2.766
49	0.99722	2.772
50		

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .88 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
1	0.88000	1.175
2	0.93808	1.539
3	0.95828	1.731
4	0.96855	1.859
5	0.97476	1.956
6	0.97892	2.032
7	0.98190	2.095
8	0.98415	2.149
9	0.98590	2.195
10	0.98730	2.235
11	0.98845	2.272
12	0.98940	2.303
13	0.99022	2.334
14	0.99091	2.362
15	0.99151	2.387
16	0.99204	2.411
17	0.99251	2.433
18	0.99292	2.453
19	0.99330	2.473
20	0.99363	2.491
21	0.99393	2.508
22	0.99421	2.524
23	0.99446	2.540
24	0.99469	2.555
25	0.99490	2.569
26	0.99510	2.583
27	0.99528	2.595
28	0.99545	2.608
29	0.99560	2.620
30	0.99575	2.631
31	0.99589	2.643
32	0.99601	2.653
33	0.99613	2.664
34	0.99625	2.673
35	0.99635	2.683
36	0.99646	2.693
37	0.99655	2.702
38	0.99664	2.710
39	0.99673	2.719
40	0.99681	2.728
41	0.99689	2.736
42	0.99696	2.743
43	0.99703	2.751
44	0.99710	2.759
45	0.99716	2.766
46	0.99723	2.773
47	0.99728	2.780
48	0.99734	2.788
49	0.99740	2.794
50	0.99745	2.801

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .89 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
1	0.89000	1.226
2	0.94340	1.584
3	0.96190	1.773
4	0.97129	1.900
5	0.97696	1.995
6	0.98077	2.069
7	0.98349	2.132
8	0.98554	2.185
9	0.98714	2.231
10	0.98841	2.270
11	0.98946	2.305
12	0.99034	2.339
13	0.99108	2.369
14	0.99171	2.396
15	0.99226	2.421
16	0.99274	2.444
17	0.99317	2.466
18	0.99355	2.486
19	0.99389	2.506
20	0.99419	2.524
21	0.99447	2.540
22	0.99472	2.557
23	0.99495	2.572
24	0.99516	2.587
25	0.99535	2.601
26	0.99553	2.614
27	0.99569	2.627
28	0.99585	2.640
29	0.99599	2.651
30	0.99612	2.663
31	0.99625	2.673
32	0.99637	2.684
33	0.99648	2.694
34	0.99658	2.704
35	0.99668	2.714
36	0.99677	2.723
37	0.99686	2.733
38	0.99694	2.741
39	0.99702	2.750
40	0.99709	2.758
41	0.99716	2.766
42	0.99723	2.774
43	0.99729	2.782
44	0.99736	2.789
45	0.99741	2.797
46	0.99747	2.804
47	0.99752	2.810
48	0.99758	2.817
49	0.99763	2.824
50	0.99767	2.830

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .9 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
1	0.90000	1.282
2	0.94868	1.633
3	0.96549	1.818
4	0.97400	1.943
5	0.97915	2.037
6	0.98259	2.110
7	0.98506	2.172
8	0.98692	2.224
9	0.98836	2.269
10	0.98952	2.307
11	0.99047	2.344
12	0.99126	2.376
13	0.99193	2.406
14	0.99250	2.433
15	0.99300	2.457
16	0.99344	2.480
17	0.99382	2.502
18	0.99416	2.522
19	0.99447	2.541
20	0.99475	2.558
21	0.99500	2.575
22	0.99522	2.592
23	0.99543	2.607
24	0.99562	2.622
25	0.99579	2.635
26	0.99596	2.648
27	0.99611	2.661
28	0.99624	2.673
29	0.99637	2.685
30	0.99649	2.696
31	0.99661	2.707
32	0.99671	2.717
33	0.99681	2.728
34	0.99691	2.738
35	0.99699	2.747
36	0.99708	2.756
37	0.99716	2.765
38	0.99723	2.774
39	0.99730	2.783
40	0.99737	2.791
41	0.99743	2.799
42	0.99750	2.807
43	0.99755	2.814
44	0.99761	2.821
45	0.99766	2.829
46	0.99771	2.836
47	0.99776	2.843
48	0.99781	2.850
49	0.99785	2.856
50	0.99790	2.862

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .91 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
1	0.91000	1.341
2	0.95394	1.684
3	0.96905	1.866
4	0.97670	1.990
5	0.98132	2.082
6	0.98440	2.155
7	0.98662	2.215
8	0.98828	2.266
9	0.98958	2.309
10	0.99061	2.350
11	0.99146	2.385
12	0.99217	2.417
13	0.99277	2.446
14	0.99329	2.472
15	0.99373	2.497
16	0.99412	2.520
17	0.99447	2.541
18	0.99477	2.560
19	0.99505	2.579
20	0.99530	2.597
21	0.99552	2.614
22	0.99572	2.629
23	0.99591	2.644
24	0.99608	2.659
25	0.99624	2.672
26	0.99638	2.685
27	0.99651	2.698
28	0.99664	2.710
29	0.99675	2.721
30	0.99686	2.733
31	0.99696	2.744
32	0.99706	2.754
33	0.99715	2.764
34	0.99723	2.774
35	0.99731	2.784
36	0.99738	2.793
37	0.99745	2.802
38	0.99752	2.810
39	0.99759	2.818
40	0.99765	2.826
41	0.99770	2.835
42	0.99776	2.842
43	0.99781	2.850
44	0.99786	2.857
45	0.99791	2.864
46	0.99795	2.870
47	0.99800	2.878
48	0.99804	2.885
49	0.99808	2.891
50	0.99812	2.898

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .92 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
1	0.92000	1.405
2	0.95917	1.741
3	0.97259	1.920
4	0.97937	2.041
5	0.98346	2.132
6	0.98620	2.203
7	0.98816	2.262
8	0.98963	2.312
9	0.99078	2.357
10	0.99170	2.395
11	0.99245	2.430
12	0.99308	2.461
13	0.99361	2.490
14	0.99406	2.516
15	0.99446	2.540
16	0.99480	2.562
17	0.99511	2.583
18	0.99538	2.603
19	0.99562	2.622
20	0.99584	2.639
21	0.99604	2.655
22	0.99622	2.671
23	0.99638	2.686
24	0.99653	2.700
25	0.99667	2.713
26	0.99680	2.726
27	0.99692	2.739
28	0.99703	2.751
29	0.99713	2.762
30	0.99722	2.773
31	0.99731	2.784
32	0.99740	2.795
33	0.99748	2.805
34	0.99755	2.814
35	0.99762	2.823
36	0.99769	2.832
37	0.99775	2.841
38	0.99781	2.850
39	0.99786	2.858
40	0.99792	2.865
41	0.99797	2.873
42	0.99802	2.881
43	0.99806	2.889
44	0.99811	2.896
45	0.99815	2.903
46	0.99819	2.910
47	0.99823	2.916
48	0.99826	2.922
49	0.99830	2.928
50	0.99833	2.935

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .93 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
1	0.93000	1.476
2	0.96437	1.803
3	0.97610	1.980
4	0.98202	2.098
5	0.98559	2.186
6	0.98798	2.256
7	0.98969	2.314
8	0.99097	2.364
9	0.99197	2.408
10	0.99277	2.445
11	0.99342	2.480
12	0.99397	2.511
13	0.99443	2.538
14	0.99483	2.564
15	0.99517	2.588
16	0.99548	2.610
17	0.99574	2.631
18	0.99598	2.650
19	0.99619	2.668
20	0.99638	2.685
21	0.99655	2.702
22	0.99671	2.717
23	0.99685	2.732
24	0.99698	2.746
25	0.99710	2.759
26	0.99721	2.772
27	0.99732	2.784
28	0.99741	2.796
29	0.99750	2.808
30	0.99758	2.818
31	0.99766	2.829
32	0.99774	2.839
33	0.99780	2.849
34	0.99787	2.858
35	0.99793	2.867
36	0.99799	2.876
37	0.99804	2.885
38	0.99809	2.894
39	0.99814	2.902
40	0.99819	2.910
41	0.99823	2.917
42	0.99827	2.924
43	0.99831	2.931
44	0.99835	2.938
45	0.99839	2.946
46	0.99842	2.953
47	0.99846	2.959
48	0.99849	2.966
49	0.99852	2.972
50	0.99855	2.978

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .94 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
1	0.94000	1.555
2	0.96954	1.874
3	0.97959	2.046
4	0.98465	2.161
5	0.98770	2.247
6	0.98974	2.317
7	0.99120	2.374
8	0.99230	2.423
9	0.99315	2.465
10	0.99383	2.502
11	0.99439	2.536
12	0.99486	2.566
13	0.99525	2.594
14	0.99559	2.619
15	0.99588	2.643
16	0.99614	2.664
17	0.99637	2.684
18	0.99657	2.703
19	0.99675	2.721
20	0.99691	2.738
21	0.99706	2.754
22	0.99719	2.769
23	0.99731	2.784
24	0.99743	2.798
25	0.99753	2.811
26	0.99762	2.823
27	0.99771	2.836
28	0.99779	2.848
29	0.99787	2.858
30	0.99794	2.869
31	0.99801	2.879
32	0.99807	2.890
33	0.99813	2.899
34	0.99818	2.909
35	0.99823	2.917
36	0.99828	2.925
37	0.99833	2.934
38	0.99837	2.943
39	0.99842	2.951
40	0.99845	2.959
41	0.99849	2.966
42	0.99853	2.974
43	0.99856	2.980
44	0.99860	2.987
45	0.99863	2.994
46	0.99866	3.000
47	0.99868	3.001
48	0.99871	3.002
49	0.99874	3.002
50	0.99876	3.003

THIS TABLE RELATES A NUMBER OF INDEPENDENT GROUPS (FIRST COLUMN)
TO AN ASSURANCE NEED (SECOND COLUMN) BASED ON A .95 DESIGN ASSURANCE
A DESIGN FACTOR IS FOUND IN THE THIRD COLUMN   (PART 1 OF 4)

NUMBER	ASSURANCE	FACTOR
1	0.95000	1.645
2	0.97468	1.955
3	0.98305	2.121
4	0.98726	2.234
5	0.98979	2.320
6	0.99149	2.386
7	0.99270	2.442
8	0.99361	2.490
9	0.99432	2.531
10	0.99488	2.568
11	0.99535	2.601
12	0.99574	2.630
13	0.99606	2.657
14	0.99634	2.682
15	0.99659	2.705
16	0.99680	2.727
17	0.99699	2.746
18	0.99715	2.765
19	0.99730	2.783
20	0.99744	2.800
21	0.99756	2.815
22	0.99767	2.830
23	0.99777	2.845
24	0.99787	2.858
25	0.99795	2.870
26	0.99803	2.883
27	0.99810	2.895
28	0.99817	2.907
29	0.99823	2.917
30	0.99829	2.927
31	0.99835	2.937
32	0.99840	2.948
33	0.99845	2.957
34	0.99849	2.967
35	0.99854	2.975
36	0.99858	2.983
37	0.99862	2.991
38	0.99865	3.000
39	0.99869	3.001
40	0.99872	3.002
41	0.99875	3.003
42	0.99878	3.003
43	0.99881	3.004
44	0.99884	3.005
45	0.99886	3.006
46	0.99889	3.006
47	0.99891	3.007
48	0.99893	3.007
49	0.99895	3.008
50	0.99898	3.009

DESIGN FORM 1-1 - PROCEDURES WORKSHEET - PERSONNEL OR MATERIEL (CIRCLE ONE)
CASE _____   UNIT _____   PAGE 1 OF 4   DATE _____

1. ESTABLISH MISSION ESSENTIAL TEAM STRUCTURE

    FOR THE FOLLOWING MISSION _____

2. ESTABLISH SUBSTITUTABILITY MATRIX.

3. RECORD DESIGN CRITERIA:

    a. DESIGN GOAL TEAM LEVEL _____

    b. DEGRADATION PROBABILITY _____

    c. MAX TEAM GOAL _____
        (Total Desired Number of MET Teams - With No Degradation)

    d. UNIT DESIGN ASSURANCE _____

4. DESIGN FORM 2P OR FORM 2M - PERSONNEL OR MATERIEL (CIRCLE AS APPROPRIATE).

    a. FILL IN CASE, UNIT, PAGE, AND DATE AT TOP OF FORM.

    b. FILL IN LINE NUMBERS (COLUMN 1).

    c. FILL IN NAMES (COLUMN 2).

    d. FOR FORM 2P ONLY, FILL IN GRADE AND MOSC (COLUMNS 3 AND 4).

    e. ENTER THE DESIGN GOAL TEAM NUMBER (COLUMN 5 FORM 2P OR 2M). FOR EACH SKILL OR MATERIEL ITEM ENTER THE NUMBER
        REQUIRED AT THE DESIGN GOAL TEAM LEVEL (COLUMN 5).

    f. FOR EACH LINE ITEM WHICH HAS OTHER THAN ZERO IN COLUMN 5, COUNT THE NUMBER OF LINE ITEMS WHICH CAN
        TRANSFER INTO THE MISSION ESSENTIAL SKILL OR MATERIEL ITEM. ENTER THIS NUMBER IN COLUMN 6.

    g. FOR ALL LINE ITEMS (WHETHER MISSION ESSENTIAL OR NOT), COUNT THE NUMBERS OF SKILLS OR MATERIEL ITEMS
        INTO WHICH THE LINE ITEM CAN TRANSFER. ENTER THIS NUMBER IN COLUMN 7.

    h. ENTER ANY REMARKS IN COLUMN 8. IF YOU WISH TO MAINTAIN A BLANK MASTER THIS IS A GOOD STEP TO REPRODUCE
        WORKING COPIES.

5. IDENTIFY ANY ZERO/ZERO CASES (AND ANY KNOWN INDEPENDENT CLUSTERS). IF THERE ARE NONE GO DIRECTLY TO PARAGRAPH 7.

    a. IDENTIFY ALL ZERO TRANSFERS IN COLUMN 6. FOR EACH CASE WHERE THE CORRESPONDING COLUMN 7 POTENTIAL
        TRANSFERS ARE ALSO ZERO, CIRCLE THE CORRESPONDING ITEMS IN COLUMN 5.

    b. COUNT THE NUMBER OF SUCH CASES, ADD ONE (UNLESS THE UNIT IS ALL ZERO/ZERO OR INDEPENDENT CLUSTER CASES)
        AND ENTER.

        _____

    c. BASED ON THE UNIT DESIGN ASSURANCE (PARA 3. d. ABOVE) ENTER THE ASSURANCE TABLES WITH THE NUMBER IN 5.b.
        ABOVE AND ENTER ASSURANCE _____

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6. ESTABLISH FENCED ADD-ONS BASED ON ZERO/ZERO AND/OR INDEPENDENT CLUSTER CASES.

    a. USE THE DEGRADATION FROM PARAGRAPH 3.b., THE ELEMENT ASSURANCE FROM PARAGRAPH 5.c.; AND THE REQUIRED NUMBER
        FOR EACH CIRCLED ZERO/ZERO AND INDEPENDENT CASE (COLUMN 5 OF FORM 2P OR 2M) TO ENTER THE REQUIREMENTS TABLES.

    b. FIND THE REQUIRED NUMBER AT THE BEGINNING OF A ROW UNDER THE COLUMN LABELED "REQUIREMENT".

    c. MOVE TO THE RIGHT TO FIND THE FIRST INSTANCE WHERE THE TABULAR ASSURANCE EQUALS OR EXCEEDS THE ENTERING
        ASSURANCE (FROM PARA 5.c., PREVIOUS PAGE).

    d. MOVE UP THE COLUMN TO FIND THE ADD-ON HEADING THE COLUMN. RECORD THE ADD-ON ON THE APPROPRIATE LINE
        OF FORM 2P OR FORM 2M UNDER COLUMN 8.

    e. REPEAT a. THROUGH d. FOR EACH ZERO/ZERO AND INDEPENDENT CLUSTER CASE.

7. ESTABLISH TRIAL LOWER BOUND FOR BRACKETING RUNS.

    a. ENTER THE TOTAL NUMBER OF PERSONNEL OR ITEMS REQUIRED FOR THE DESIGN GOAL TEAM (COLUMN 5 SUM) _____.

    b. ENTER THE DEGRADATION PROBABILITY FROM PARAGRAPH 3.b._____.

    c. ENTER ONE MINUS THE DEGRADATION PROBABILITY_____.

    d. MULTIPLY 7.a. BY 7.b. DIVIDE BY 7.c. AND ENTER_____.

    e. IF NOT A WHOLE NUMBER, RAISE 7.d. TO THE NEXT HIGHER INTEGER AND ADD TO ALL ZERO/ZERO AND INDEPENDENT
        CLUSTER REQUIREMENTS FROM COLUMN 8.

    f. RECORD THE LOWER BOUND TOTAL HERE AND AS THE CASE NUMBER HEADING COLUMN 28 IN DESIGN FORM 5._____.

8. ESTABLISH TRIAL UPPER BOUND FOR BRACKETING RUNS.

    a. COUNT THE NUMBER OF ZERO/ZERO AND INDEPENDENT CLUSTER CASES _____.

    b. COUNT THE REMAINING REQUIRED STRENGTH (NON ZERO/ZERO OR INDEPENDENT CLUSTER ITEMS FROM THE DESIGN GOAL TEAM
MET) _____.

    c. COUNT THE REMAINING REQUIRED LINE ITEMS(NUMBER OF NON ZERO/ZERO OR NON CLUSTER ROWS IN SUBSTITUTION
        MATRIX) _____.

    d. DIVIDE c. BY 2 _____.

    e. ADD a. AND d. _____.

    f. USING UNIT DESIGN ASSURANCE FROM 3.d., ENTER THE APPROPRIATE TABLE FROM ANNEX B WITH "NUMBER" FROM e.
        (ROUNDED UP IF NECESSARY). RECORD "FACTOR" _____.

    g. DIVIDE b. BY d. _____.

    h. MULTIPLY DEGRADATION PROBABILITY (7.b.) _____ BY ONE MINUS THE DEGRADATION PROBABILITY (7.c.)
        _____ BY g. AND RECORD ON TOP OF NEXT PAGE.

    i.   _____ MULTIPLY THE SQUARE ROOT OF THIS NUMBER BY d., THEN BY f., AND THEN DIVIDE BY 7.c. TO GET THE VARIABILITY ADD-ON _____.

    j.   RAISE i. TO THE NEXT HIGHER POWER OF 2 (2, 4, 8, 16, 32, 64, ETC.)_____.

    k.   ADD j. DIVIDED BY 2 _____ TO 7.f. _____ TO GET MIDDLE BOUND CASE NUMBER_____. RECORD ALSO AT THE TOP OF COLUMN 29 ON FORM 5 AS THE CASE NUMBER.

    l.   ADD j. _____ TO 7.f. _____ TO GET UPPER BOUND CASE NUMBER _____. RECORD ALSO AT THE TOP OF COLUMN 30 ON FORM 5 AS THE CASE NUMBER.

9. ESTABLISH PRIORITIES (DESIGN FORMS 2P OR 2M AND 3)

    a.   FILL IN CASE, UNIT, PAGE, AND DATE AT TOP OF FORM 3.

    b.   FILL IN LINE NUMBERS (COLUMN 10 OF FORM 3).

    c.   IDENTIFY ANY CONSTRAINTS ON POSSIBLE ADD-ONS UNDER COLUMN 11 OF FORM 3.

    d.   COPY COLUMN 8 UNDER COLUMN 12.

    e.   PUT AN X UNDER COLUMN 13 FOR EACH LINE NUMBER WITH NO DESIGN MET REQUIREMENT.

    f.   UNDER COLUMN 17, ENTER (TO THE NEAREST TENTH WHERE AN ADD-ON IS NOT CONSTRAINED UNDER COLUMN 11) THE LOWER BOUND (7.f.) DIVIDED BY THE MET TOTAL (7.a.) TIMES THE MET REQUIREMENT FOR EACH LINE.

    g.   UNDER COLUMN 18, ENTER (TO THE NEAREST TENTH WHERE AN ADD-ON IS NOT CONSTRAINED UNDER COLUMN 11) THE UPPER BOUND (8.1.) DIVIDED BY THE MET TOTAL (7.a) TIMES THE MET REQUIREMENT FOR EACH LINE.

    h.   UNDER COLUMN 14, USE COLUMN 6, THE LIMITS OF COLUMNS 11-13, AND THE IMPLIED REQUIREMENTS OF COLUMNS 17 AND 18 TO ESTABLISH PRIORITIES FOR SKILLS OR ITEMS TO BE ADDED

    i.   IF NOT APPROPRIATE TO ADD THE PRIMARY SKILL OR ITEM, ESTABLISH ALTERNATIVE SUBSTITUTES UNDER COLUMN 15. RECORD THE SUBSTITUTE LINE NUMBER RATHER THAN A PRIORITY NUMBER UNDER COLUMN 15.

10. APPLY PRIORITIES. (DESIGN FORMS 3 AND 4.)

    a.   FILL IN HEADING OF DESIGN FORM 4.

    b.   ON DESIGN FORM 4, NUMBER THE PRIORITIES UNDER COLUMN 21.

    c.   UNDER COLUMN 22 ASSOCIATE WITH EACH PRIORITY (FROM b.) A LINE NUMBER SKILL OR MATERIEL ITEM TO BE COVERED IN THE ADD-ON.

    d.   UNDER COLUMN 23 SHOW THE LINE NUMBER TO BE ASSIGNED (COULD BE A SUBSTITUTE).

    e.   UNDER COLUMN 24 SHOW HOW MANY OF d.ARE TO BE ADDED.

    f.   DRAW A LINE WHEN THE ACCUMULATION UNDER COLUMN 24 SATISFIES THE LOWER BOUND.

    g.   DRAW A LINE WHEN THE ACCUMULATION UNDER COLUMN 24 SATISFIES THE UPPER BOUND.

11. DEVELOP AMORE INITIAL STRENGTH ENTRIES TO REPRESENT EACH DEVELOPED CASE (DESIGN FORM 5).

    a. FILL IN HEADING INFORMATION.

    b. LIST THE DESIGN MET REQUIREMENTS BY LINE NUMBER UNDER COLUMN 26.

    c. ENTER THE DESIGN GOAL STRENGTH FROM COLUMN 5 UNDER COLUMN 27.

    d. APPLY THE PRIORITIES FROM DESIGN FORM 4 TO COLUMN 27 TO OBTAIN THE LOWER BOUND CASE INITIAL STRENGTH (COL 28).

    e. APPLY THE PRIORITIES FROM DESIGN FORM 4 TO COLUMN 28 TO OBTAIN THE MIDDLE BOUND CASE INITIAL STRENGTH (COL 29).

    f. APPLY THE PRIORITIES FROM DESIGN FORM 4 TO COLUMN 29 TO OBTAIN THE UPPER BOUND CASE INITIAL STRENGTH (COL 30).

    g. CIRCLE THE ENTRIES WHICH ARE CHANGED FROM COLUMN 27 BY PRIORITY ADD-ONS. PLACE THE PRIORITY NUMBER
       TO THE UPPER RIGHT.

    h. PLACE THE TOTAL INITIAL STRENGTH AFTER THE LAST LINE ENTRY UNDER COLUMNS 28 THROUGH 30.

12. DEVELOP SUBSEQUENT CASES BASED ON THE AMORE RUN RESULTS.

    a. CIRCLE "MAKE" OR "FAIL" ACCORDING TO THE RUN OUTCOMES FOR EACH CASE WHICH EITHER MET THE DESIGN CRITERIA
       OR FAILED TO MEET IT.

    b. USING PRIORITIES DEVELOPED ON DESIGN FORM 4, SPLIT SUBSEQUENT BRACKETS BY DEVELOPING NEW CASES WITH LESS
       ADD-ONS THAN A "MAKE" RESULT AND MORE ADD-ONS THAN A "FAIL" RESULT UNTIL A CHANGE OF ONE ADD-ON HAS BEEN MADE.

    c. EITHER JUDGE SUCCESS BY THE LEAST ADD-ON THAT MET THE DESIGN CRITERIA OR DEVELOP ALTERNATIVES UNDER THE
REMAINING COLUMNS.

    d. SIGNIFICANT SURPLUSSES SHOWING UP IN THE ACCEPTED RUN CAN BE USED TO ATTEMPT TO ESTABLISH A NEW
       BOUNDING BRACKET TO REDUCE REQUIRED STRENGTH FURTHER.

13. TEST THE ACCEPTED STRENGTH AGAINST THE REQUIREMENTS OF THE FULL MET WITH ZERO DEGRADATION.

    a. TWO ITERATIONS ONLY NEED BE RUN.

    b. IF THE BEST CASE FAILS TO MEET THE FULL MET, ADJUST THE COMPOSITION (OR, IF NECESSARY THE STRENGTH)
       OF THE BEST CASE.

DESIGN FORM 2P - PERSONNEL
CASE _____   UNIT _____   PAGE ____ OF _____   DATE _____

| 1 | 2 | 3 | 4 | 5 | 6 TRANSFERS POSSIBLE INTO THIS | 7 TRANSFERS POSSIBLE FROM THIS | 8 | 9 |
| | | | | DESIGN GOAL | SKILL, | SKILL, | ZERO/ZERO ADD ONS | |
LINE NUMBER	SKILL NAME	GRADE	MOSC	TEAM_____	IF RQD	IF AVAIL	(FENCED)	REMARKS

DESIGN FORM 3 - PRIORITIZATION - PERSONNEL OR MATERIEL (CIRCLE ONE)

CASE _____   UNIT _____   PAGE ____ OF _____   DATE _____

| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

	_____EXCLUSIONS_____			_____PRIORITIES_____						
	first:	second:	third:	first:	second:	third:	fourth:	fifth:	sixth:	
LINE	MAXIMUM	FENCED	NOT ON	LEAST CAN	CAN SUBS	AVAIL OF	LOWER	UPPER	USER	
NUMBER	ADD-ON	(COLUMN 8)	MET	SUBS FOR	FOR MOST	LINE ITEM	BOUND	BOUND	CHOICE	REMARKS

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DESIGN FORM 4 - PRIORITIZATION LISTING - PERSONNEL OR MATERIEL (CIRCLE ONE)

CASE _____ UNIT _____ PAGE ____ OF _____ DATE _____

21	22	23	24	25
PRIORITY NUMBER	LINE NUMBER REQUIRED	LINE NUMBER ASSIGNED	FINAL ADD ONS (INCLUDING COLUMN B)	REMARKS

DESIGN FORM 5 - AMORE INITIAL STRENGTH ENTRY - PERSONNEL OR MATERIEL (CIRCLE ONE)

CASE _____   UNIT _____   PAGE ____ OF _____   DATE _____

26	27	28	29	30	31	32	33	34	35	36
	DESIGN GOAL STRENGTH	LOWER BOUND	MIDDLE BOUND	UPPER BOUND						
LINE NUMBER	(COLUMN 5)	CASE_____ MAKE/FAIL?	CASE_____ MAKE/FAIL?	CASE_____ MAKE/FAIL?	CASE_____ MAKE/FAIL?	CASE_____ MAKE/FAIL?	CASE_____ MAKE/FAIL?	CASE_____ MAKE/FAIL?	CASE_____ MAKE/FAIL?	CASE_____ MAKE/FAIL?